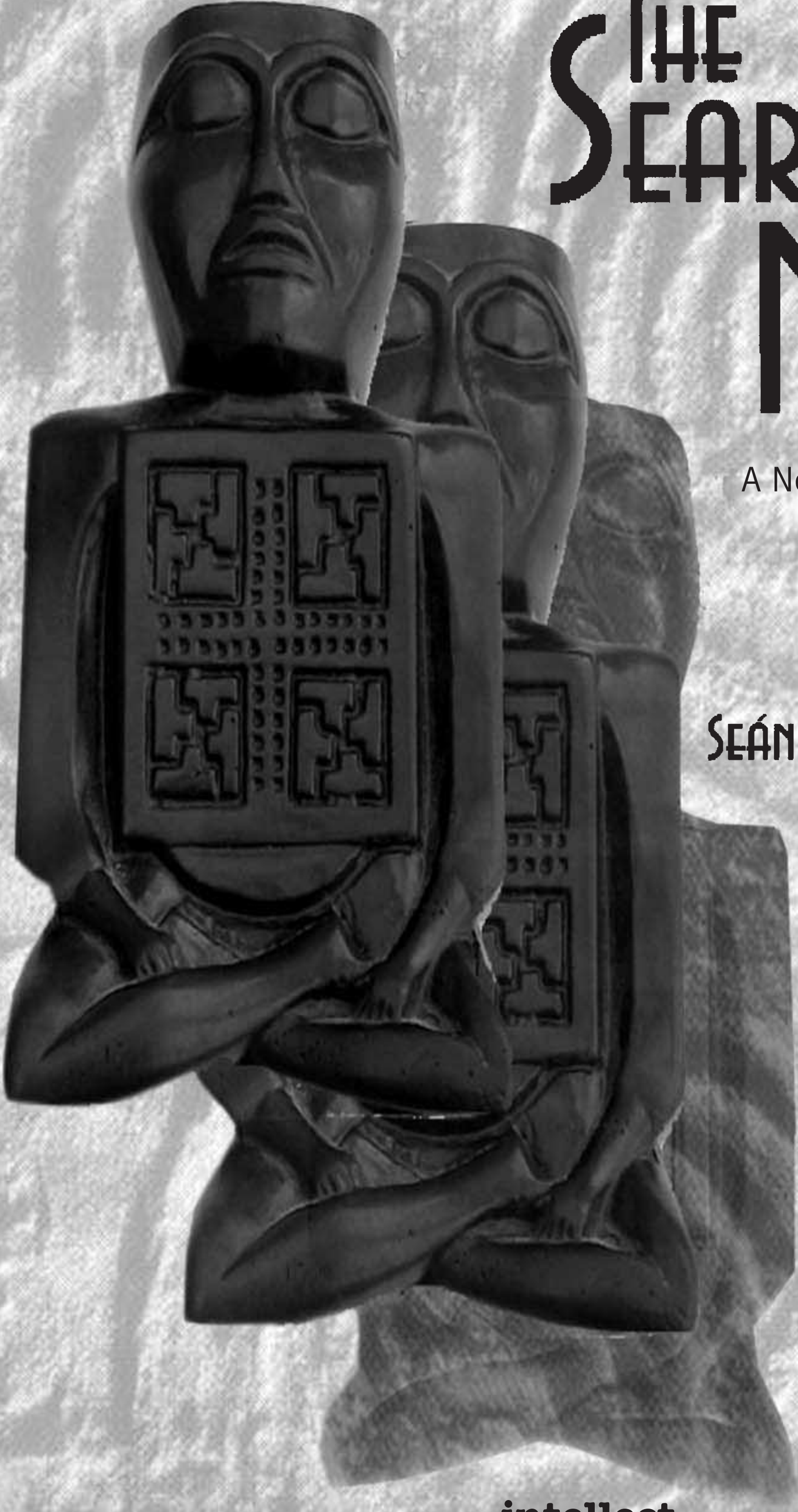

The Search for Mind

A New Foundation for Cognitive Science

Seán Ó Nualláin

intellect

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Preface

Since this book first came out in 1995 to gratifying reviews, the ante has gone up considerably for it and related enterprises. For a start, practically all the material it covers is available on the web; secondly, encyclopaediae of cognitive science (here, CS) are beginning to proliferate. This makes the job of synthesis ever more important. Readers looking for new material would be better rewarded by this book's companion volume *Being Human* (nothing to do with the Robin Williams movie!). I have left the text of the 1995 book essentially intact, and updated sections like neuroscience that have at least given the impression of rapid change. Neural simulation software and ancillary material can be found at www.nous-research.com/tools

In the intervening years, several themes from this book became the *leitmotifen* of various international conferences. Both www.nous-research.com/mind1 and www.nous-research.com/mind4 feature conferences discussing the tangled relationships between consciousness, cognition, spirituality, and cosmology. www.nous-research.com/LVM explored the commonalties and otherwise of the modalities of language, vision, and music discussed in Chapter 7. www.nous-research.com/GUT takes up a theme from Chapter 4 on the possibility of a grand unified theory of language. www.nous-research.com/mind3 explored spatial cognition, and with it one future path for AI research suggested by this book.

And yes, it's time for that anti-acknowledgement section again. The Dublin Gardai (cops), diligent as ever, busted Melanie and me on our way home yet again as they kept the Dublin streets safe from cyclists. The positive side; I wish to thank Melanie, my colleagues in the Irish Comhaontas Glas/Green Party, my squash team-mates at Trinity, the Cistercian monks of Ireland, Judge Louise Morgan, and all others who managed to stay sane as Ireland suffered an economic 'boom'. Let's hope it's the last. Abroad, thanks to Jacob Needleman, Neil Scott, Charles Fillmore, Jerry Feldman and the Mahe family of Guisseny, Brittany.

I dedicate this edition to the memory of my parents, Ettie (1916-1976) and Michael (1920-2000) who, depending on what view on monism/dualism is correct, are finally at peace or have a whole lot to catch up on.

Introduction

0.1 In search of mind

At the time of writing, Cognitive Science (CS) is academia's best shot at an integrated, multi-disciplinary science of mind. If its ambitions could even partially be realized, the importance of such a science cannot be overstated. Our view of the mind not only shapes our view of ourselves; less obviously, it also shapes our view of that part of our experience we conceive of as dealing with the external world. As we learn about the structure of this aspect of experience, we find that the world presents itself to consciousness only after being mediated to lesser or (more often) greater extents by mental structures and processes. Consequently, truly to realize the ambitions of a science of mind does not solely involve learning about such issues as how we know, perceive and solve problems; it involves finding out to what extent the world outside us is knowable by us, and indeed prescribing the limits of inquiry for disciplines like Physics which claim to afford knowledge of the external physical world.

Small wonder, then, that the stakes in this field should be so high. The contest has been so fierce, and the evidential standards assumed for science so restrictive, that there still remains a degree of skepticism abroad that academia can deliver a science of mind that does justice to the overwhelming bounty of human conscious experience while remaining constrained by the rather medieval intellectual ascesis of current Western Science. A cursory scan of the racks at any major magazine shop or bookstore will yield a vast harvest of titles (at least one of which will be the "Science of Mind") which attempt to satisfy the human hunger for some degree of self-understanding through disciplines ranging from the wacky through that application of accumulated human wisdom we call common sense. That the higher insights of this residue are still outside our purview in academia is our loss.

The reasons for this intellectual bereavement rest in scientific method's insatiable drive for ever harder i.e. more externalized evidence. The details of this issue as well as that of the rest of this section need not concern us here (I have dealt with them in Ó Nualláin (1994)). To return to the main theme, CS and the science of mind, we should note that CS is now being attacked with a great deal of justification precisely for its perceived inability to deal with experience itself as attempted in consciousness studies, and the emotional and social factors which play a large part in the infrastructure of experience. The insight which originated CS and which comprised the greater part of its seed capital, often stated in oversimplified fashion as "the brain is a computer and mind is a set of programs run on this computer," precluded the acceptance of these factors. It is now clear that, its original momentum exhausted, there is a host of problems with the view of mind and its proper study given rise to by this insight.

In the wake of this debate, a second issue, that of the degree to which CS is an integrated subject, arises. One problem is the sheer range of disciplines included in CS;

the subjects examined here, i.e. philosophy, psychology, linguistics, neuroscience, artificial intelligence, ethnoscience, ethology and consciousness studies are each masterable only by a scholar of rare gifts. To complicate matters further, they each admit of numerous subdivisions, by no means exhaust the domain inhabited by researchers who consider themselves cognitive scientists and, finally, are extremely diverse. We need to see if there are any precedents. Biochemistry, says one account, existed as a subject in the 1950s before it found a proper focus in the gene. A series of such proposals has been made for CS by such workers as Fodor and Pylyshyn (Von Eckardt 1993). In general, academic programs in CS have built themselves explicitly or implicitly on such proposals. However, the resulting structures are riddled by the tension which arises when CS strives for the "science of mind" mantle. An alternative view is that CS is yet another academic animal looking for an ecological niche. As it evolves, it usurps new areas of academic inquiry (like consciousness) and needs a single unifying principle no more than Physics does. At this stage in the development of their subject, the members of a Physics department lack a common language through which to communicate all their ongoing work. Why expect CS to be different? As we see below, this book attempts at least to arrest the momentum of the confusion of tongues in CS, where, as exemplified by psychology's history, it is a more serious problem than for physics. While its main business is the intuiting of a view of mind compatible with the major findings from relevant disciplines, it also explores precisely how the information-processing tenet at the root of CS can be extended in a principled way to answer the current criticisms. With this extension also comes a recognition of its own true central role in a federation of mind sciences.

It is fair to say that CS is currently perceived, particularly by its critics, as dependent on a notion of mind as a set of programs. That this view is a simplification need not concern us here; the situation in all its real complexity is discussed at length throughout this book (particularly in chapter 5, and in Ó Nualláin, 1994). We can learn much from the problems it poses.

For the moment, let's glance at a few of them. First of all, we don't seem to be able to write such programs ourselves outside a few carefully-chosen applications, despite our best efforts (chapter 5). Secondly, some programs which are being written on the basis of a theory of neural functioning have a structure which compromises the traditional dichotomization of program and computer architecture (chapter 4). Thirdly, the evidence that the mind is wholly material in the rather outdated sense that this word "material" is currently used is not quite as compelling as is occasionally claimed (chapter 1). To establish the validity of the computational metaphor any further requires that we establish materialism.

We might also ask whether the computationalist approach, taken to the point where it is used to constrain the data acceptable in CS, risks omitting much valid data about cognition. It may, for example, require that we jettison emotion and consciousness, which seems on common-sense grounds a bad move. It is argued in chapters 2 and 8, respectively, that these factors must be included. In particular 2.1.4.1 shows how emotion can be regarded as rational and therefore as cohering to an expanded, more

encompassing view of knowledge. A further question is whether a concept as minimalist as computation can bear the burden of knowing in all its forms.

Occasionally, diverging from conventional CS, we'll make reference as well to thinkers who have treated mind as something immanent in nature, i.e. an ordering principle in nature (the Greek word *nous* is used to capture this aspect of mind). The work of at least one of these thinkers, Gregory Bateson, has become relevant to AI and we'll consider it in that context. In part one, however, we're essentially reviewing the sub-disciplines which comprise CS. No previous knowledge of any of these disciplines is assumed. The major findings of the area are introduced, often through outlining a brief history of the area, as well as those techniques without mastery of which no progress can be made in understanding further theoretical discussion. The path taken through each discipline is presuppositionless, i.e. we are analyzing each field on its own merits on these paths. The areas of contention, and the manner in which they relate to CS, emerge naturally. In such a vast field as CS, it is unwise to take the methodology of any single area, even if in the case of AI it is the area which excited much of the current interest in CS, beyond its own domain.

0.2 The field of Cognitive Science, as treated in this book

Cognitive Science is a discipline with both theoretical and experimental components which, inter alia, deals with knowing. In doing so, it quite often finds itself walking in the footprints of long-dead philosophers, who were concerned with the theory of knowledge (epistemology). A lot of the considerable excitement in the area derives from its ability to experimentally test conjectures of these great minds, or on occasion to establish that these conjectures are too abstract to be so tested.

The disciplines which together traditionally comprise the core of CS are AI, Linguistics, Philosophy (including Philosophy of Mind and Philosophical Epistemology) and Cognitive Psychology. The boundary disciplines are Neuroscience, Ethnoscience and Ethology. These latter three disciplines are, respectively, the study of the brain and central nervous system; the study of cognition in different cultures; finally, the study of animal and human behaviour in natural environments. The first task of this book is to give a clear account of all the above-named disciplines, where they relate to cognition, with an indication of the direction of the currently most exciting lines of research. A more detailed outline of the structure of these accounts is given below.

It is fair to say that CS is currently in ferment, with all the apparent chaos and promise which that term connotes. On the one hand, the variety of disciplines which comprise CS are foci of intensive research effort. On the other, in the case of several of the disciplines, the intensity of this research effort has had reverberations which threaten to undermine the methodological foundations of the discipline. The clearest example of this is AI.

It is worthwhile for a variety of reasons to immerse oneself in the philosophical antecedents of current CS. Even a cursory glance at the history of philosophy reveals some marvels as philosophers struggle conceptually with the notion of computation. The notion of an "Ars Magna," a general computational device, goes back at least a

millennium in European and Arabic thought, starting with the Spaniard **Ramon Lull**, extending through the experimental devices of Leibniz and Pascal before culminating in Turing's and Church's work.

In parallel with the struggle with the notion of computation was that with the more general problem of knowledge. The lines of approach taken to this problem were extremely varied. The key to the myriad conceptions of knowledge which arose is consideration of the problem of the relationship between mind and world. These conceptions, diverse and theoretical though they are, often find themselves incarnated in the design principles of AI systems. Moreover, speculations about the origins of knowledge often find themselves subject to experimental test in psychology. This multi-faceted, sometimes implicit and sometimes explicit, relationship which exists between philosophical epistemology and Cognitive Science is a major theme of this book. In a limited sense, CS is and always has been epistemology; just to what extent this is the case is the focus here. We shall find that even the specifics of AI techniques were often foreshadowed in philosophy.

CS would be pointless were it not to lead to a theory of cognition. Ideally, this theory should have psychological and computational consequences. The former should possess "ecological validity" i.e. it should inform about real everyday life in a real environment. The latter should lead to recommendations both for implementations in AI systems as well as occasionally for the pointlessness of attempting such implementation. The book ends with such a theory of cognition.

CS has traditionally ignored emotion (which seemed irrelevant) and social factors in cognition, in the latter case on the basis that these factors must be in some sense processed, and could consequently be properly treated simply by complete explanation of the operations of the processor. It is hoped that by the end of this book the reader will be convinced of the necessity of granting autonomy to these factors.

0.3 History of Cognitive Science

To understand why these factors have been ignored, it is necessary to delve a little into the history of CS. There are many histories in this book, most of them brief, and this is to be one of the briefest. I am concerned only with outlining in the most general terms how CS has arrived at its present juncture. It will be re-iterated time and again in the course of this book that in a "science of mind" sense CS has always existed. the criteria current in any culture for "science" may change greatly, but there always has been and always will be a science which deals with mind. Two events stand out in the formation of modern CS. One is the Hixon symposium at Caltech in 1947 on "Cerebral Mechanisms in Behaviour." The major significance of this symposium lay in the algorithmic analysis of complicated behavioural sequences by the neuroscientist Lashley. A major consequence of this was that the contemporary dominant paradigm of Psychology, i.e. Behaviourism (chapter 2) lost what would have seemed to be its most sure ally.

Models from formal logic were beginning to inform the neuroscience of such brilliant thinkers as Warren McCulloch (1989) by the 1930s and he produced a model of neuronal function with this conceptual motivation. In the meantime, linguists were

beginning to produce a formal theory of their area culminating in the work of Chomsky (chapter 3). Phenomena in cognition were being subjected to informational analysis (chapter 2) and the beginnings of Artificial Intelligence, which we discuss in chapter 5, were bearing fruit in abundance. By 1956, these strands were pulled together in a Symposium on information theory at MIT Cognitive Science effectively had arrived. funding from the Sloan Foundation ensured its continuation.

The success of computing has ensured that computation is the dominant paradigm in CS. However, as we discuss in chapter 5 in particular, computation is a minimalist concept and a great deal more infrastructure must be added to lay a possible foundation for the discipline. The resulting framework has yielded many interesting results like the work of Marr and Kosslyn (Gardner, 1985). However, attacks have recently been launched on this paradigm, inter alia by Searle (1992), chiefly on its ignoring of consciousness; by Edelman (1992) also on its ignoring biology and the assumptions it makes about the structure of the world and the consequent relationship of mind and world; finally, by the current author (1993a) on various grounds, including its mistaken view of mind.

We shall review this material time and again in the course of this book. It is apposite to quote the director of the French national initiative in CS, André Holley, (1992, p. 1) to close this section:

"In the pages which follow, the picture of a fully mature science with its own methods, achievements and concepts will not be found… the objective and condition of existence of cognitive science requires that these diverse and insulated perspectives should open, exchange more methods and concepts, and develop a common language" (Translation by the present author)

That neatly summarizes the goals of this book.

0.4 Topics treated

As may be expected, the first chapter deals mainly with philosophical epistemology. Equally inevitably, it abounds in "isms" like realism, historical nativism, and nominalism. These terms will recur in different contexts throughout the book, so a glossary is supplied at the start of the chapter. We will find that the arguments – presented in historical sequence – using these terms have enormous relevance to present-day AI, in particular. Most importantly, it will become clear that the most pressing current debate in AI – that concerning situated, embodied intelligence – was presaged in the debate surrounding the French philosopher Maurice Merleau-Ponty. We then concern ourselves with the appropriate relationship of the philosophy of mind to cognitive science. Finally, the epistemological stance taken in this book is detailed.

Chapter 2 deals with cognitive psychology. We first of all describe the different approaches to experimental psychology which have been attempted. We examine some of the valid results obtained from each of these approaches while beginning to examine the concept of psychology as experimental epistemology. This done, we find that we cannot sensibly discuss knowledge without taking its development in the individual into account. This leads us naturally to the discipline of genetic epistemology, as pioneered by the Swiss Jean Piaget. As was the case with Merleau-Ponty, we find there

is almost as much to learn from criticism of Piaget as there is from his brilliant restatement of the central question of knowledge: How does knowledge develop? A new theme emerges, crescendo: we need a central notion of equilibration, i.e. the paradoxical need for stability, but at a level of increased mastery of the environment, in order to explain the process of cognitive development. It is found, moreover, that the epistemological stance of chapter 1 is consistent with the lessons learned from both the strengths and weaknesses, of the work of Piaget and J J Gibson. The latter's work leads us to consider the troubled issue of the relationship of perception to cognition.

There are still those who say that knowledge is essentially linguistic, that language is an innate capability, and that knowledge unfolds in accordance with a pre-determined genetic instruction. In the third chapter, we shall analyze the attempts of linguists to characterize this innate capability, whether it is considered co-extensive with thought or not. We will find that such attempts at a monolithic formalization all seem to fall short. Situated cognition in non-symbolic contexts like a robot's perception-action connection is easy to elucidate. one of the major tasks of the linguistics chapter is to consider the nature of symbolic situated cognition through analysis of the notion of context.

It certainly will be a long time before the neurological processes supporting linguistic activity, in the biochemical process supporting unfolding of the DNA's germ of language, are isolated. Chapter 4 focuses on what actually is known about the brain in terms of its anatomy, localizations (and otherwise) of function, transmission of nerve impulses and how these facts were discovered. We find ourselves en route considering the burgeoning sub-discipline of connectionism as its alter ego of experimental neuroscience. One issue in particular haunts this chapter: what is the relation between neurophysiological and symbolic functioning? We discover that this question can be answered properly only by positing a hierarchy of other levels between the two. The raising of a second issue, that of how the brain adapts itself to the environment, results in the conclusion that a Darwinian struggle between neural groups takes place. We find in this a neural mechanism to implement "equilibration" aka (also known as) "The Principle of Rationality."

People skeptical about AI are often criticized for being purely destructive i.e. not producing the ideas they feed on. How better to refute this than by using AI skeptics to introduce the main AI techniques! Some of these gentlemen (Husserl, Wittgenstein) were unfortunately not alive to disbelieve in AI when it came around, but they showed every sign of shaping to spoil the fun, in that they produced theories of mind resembling AI formalisms and then proceeded to refute them. We then get down to the serious business of considering the applications which AI has actually achieved. It is found that the most useful categorization of these applications is with respect to a sub-symbolic/syntactic/semantic triad. En route, we discuss how AI has, sometimes harmfully, set the agenda for discussion of the foundations of CS. When we finally get down to discussing the current methodological debate in AI we find ourselves in a situation similar to the crises in philosophy and cognitive psychology which attracted our attention at the end of those chapters.

Ethnoscience and ethology occupy us briefly before we come to Part 2. In Ethnoscience, we find it established that classification is done opportunistically within certain general universal constraints by the human mind. Ethology leads us to a discussion of sociobiology, and en passant the nature of evolution itself.

In Part 2 the main conclusions from Part 1 first are summarized. Then a set of attributes common to all symbolic functioning is proposed. It is seen to be valid for language and vision, and to gain in strength from brief consideration of music as a formal system. A summary of the ways in which these systems resemble each other is presented.

Finally, it will have become clear that we cannot discuss cognition without detailed reference to its development. We find that such development requires changes both within the subject and the subject's world which require us to introduce the concept of consciousness which mediates subject and object. Nor can we speak very long about this without reference to the individual in her social context. A final chapter then reviews all the themes which have emerged and synthesizes them in an overall theory of cognition and its development. It considers also what the future shape of CS is likely to be.

0.5 User's guide to this book

Having written about the structure of the book, I'd like to point out some aspects of its style. This does not claim to be the final word on any of these disciplines, or indeed anything but a readable introduction to each. As has been mentioned, the current controversies are allowed to enter naturally, and the point of view taken is then spelled out, when appropriate with supporting argument. On occasion, the reader is pointed to a reference which provides this argumentation, particularly if it is peripheral to the major concerns of the book.

CS is such a vast area that the most one can hope to do is to deliver an overall impression on where the area is at present, and where it might go. Moreover, each of the constituent disciplines, as I repeat throughout the book, strives for domination of the whole area. My own academic formation was in Psychology and Computer Science. I worked in Computational Linguistics for the past decade. It is inevitable that this book will reflect my own experience, often in ways of which I am not wholly conscious.

Technical terms are introduced as gently as possible, either with a glossary or by giving a definition alongside the first occurrence of the term. Every book creates its own language and I shall have achieved much if by chapter 9 you are speaking mine. The diagrams feature, among other characters like the pint-swilling robot, a figure loosely based on the great Irish comic writer, Myles na gCopaleen (aka Brian Ó Nualláin, his real name, or Flann O'Brien, the more famous pseudonym). In his honor, the main position emerging from chapter 1 is termed the Mylesian position, and the overall view the Nolanian position, which is the English form of both our names. After a decade of teaching, I found that learning occurs best with an admixture of comic anarchy which is why Myles was hired.

A great deal of this material has been successfully presented to Computer Science, Computational Linguistics, Cognitive Science and Electronic Engineering students, both undergraduate and postgraduate. For the reader's information, it should be stated that Sections 3.3 and 3.7 in this book can be passed safely by the reader without losing any continuity in the point the book is making. I invite you to share the excitement of a discipline which will certainly fundamentally change how we think of ourselves and our relationship to our world.

0.6 Further Reading

The Mind's New Science (Gardner, 1985) is an excellent historical introduction to each of the disciplines which comprise CS. At the time of writing, it is a little out of date. *The Computer and the Mind* (Johnson-Laird, 1988, 1993) is a more technical, strongly computational introduction. The Journal of the French National Research Center produced a special issue in October 1992 featuring one-page summaries of the major research ongoing in France, which is often a great deal intellectually more open than that in the English-speaking world. Many more references will be given in the course of this text to books with strengths in particular areas of CS.

Part 1 – The Constituent Disciplines of Cognitive Science

1. Philosophical Epistemology

Glossary

Empiricism states all knowledge comes from the senses: its opponents are rationalists and idealists.

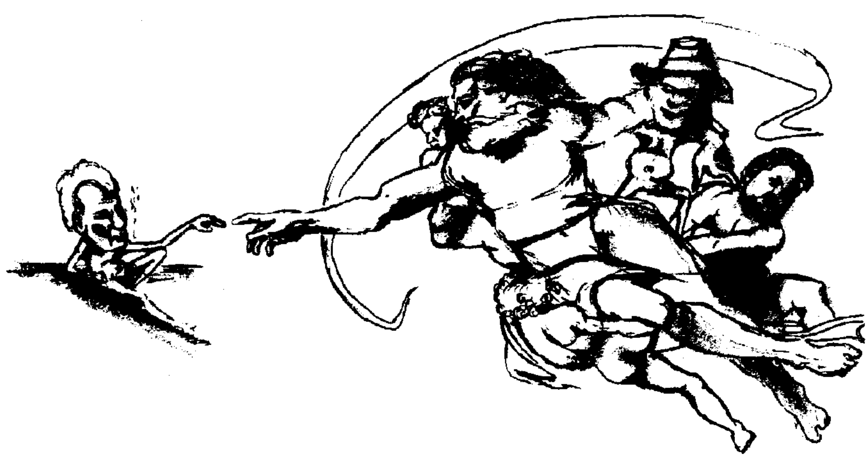
Rationalism states that all knowledge comes from mental operations.

Idealism states that knowledge is essentially a trickle©down from a world of ideas.

Innatists believe that knowledge is genetically or otherwise inherited. Their natural enemies are also empiricists.

Kantians believe that knowledge derives from sense-data mediated through mental structures which they call categories.

Conceptualists believe that concepts are naturally-occurring aspects of reality.



Nominalism states the opposite, i.e. that a concept is just a name.

Materialists hold that mental properties are in some way an aspect of matter.

Their allies are *Reductionists*, who won't be happy until all mental activity can be reduced to description in purely physical terms.

There is also an *eliminativist* (another buzzword) tendency about this latter trio, who have as their common enemy:

Dualists, who hold that there is a spiritual principle at work in mind, together with the material processes and

Holists, who claim that there are whole-properties associated with any biological processes from the level of the cell upward, and who insist the same about mind.

Realists insist that knowledge is impressed in the mind directly by objective properties of the world. They hate Idealists.

Situatedness: The notion that all of Cognition is profoundly affected by the physical and social situation in which they take place. It is related to

Embodiment: The notion that Cognition can only be considered with respect to the co-presence of a body and also to

Mundanity: The notion that mind, body and world are different, but profoundly interrelated and can best be considered together.

Existentialism is the school whose slogan is "existence precedes essence," i.e. we should attend to the necessary facts surrounding our immediate existence before launching into theory.

Reductionism attempts to describe mental activity in observable neural events.

Eliminative materialists attempt to do away with all the common concepts of "folk psychology" like belief and desire, describing these entities purely in physical terms.

The *philosophy of mind* deals with the analysis of certain psychological constructs. These include propositional attitudes, which are terms which relate subjects to hypothetical objects, e.g. "believe" in "X believes Y."

Functionalism is the doctrine that mental processes have "multiple realizability," i.e. it is irrelevant to their formal analysis whether they are run on my brain, your brain, a

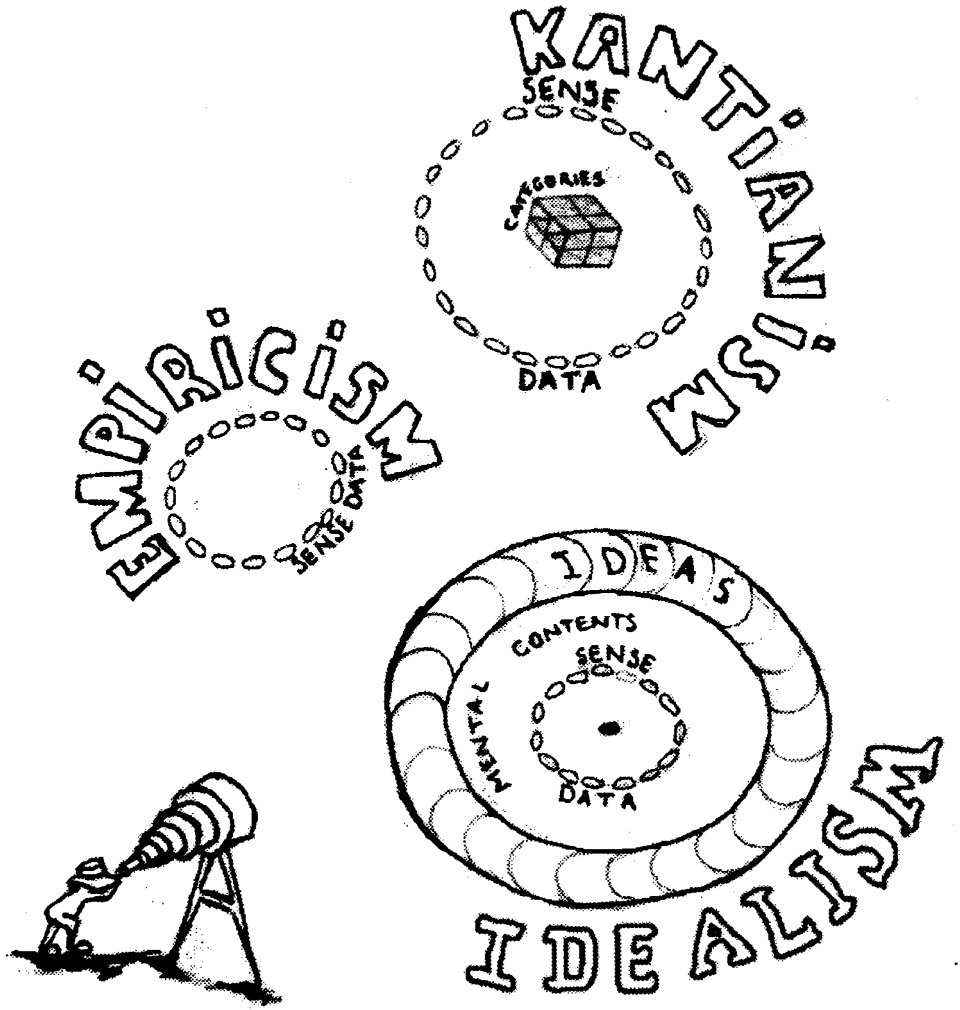


Figure 1.1

computer, or an assembly of tin cans. Functional equivalence thus falls under that category of equivalence analysis called

Token-token analysis, which is satisfied with demonstration of equivalences under some system of identification or other. In contrast, type-type analysis insists on the more stringent requirement of physical identity.

Intentionality: As originally formulated by Fr Brentano, it points out as a crucial property of mental states the fact that they point to objects. It must be clearly distinguished from any of the connotations of its colloquial association with "will."

I refrain for now from attempting to define:

Consciousness
Being
Knowledge

The diagrams in Figure 1.1 all have a ring of beads representing disjoint sense-data. A solid ring represents structured sense-data. The inner space represents mental contents.

Mind has not yet been defined: where does it fit in these diagrams?

1.0 What is Philosophical Epistemology?

A short answer to this question is that it is the theoretical approach to the study of Knowledge. It can be distinguished, in these terms, from experimental epistemology which features in the remainder of the disciplines within Cognitive Science.

Philosophy (literally, love of knowledge or wisdom) has recently had a very bad press. As we shall see, it used to comprise disciplines like physics, chemistry and mathematics, all of which in turn broke away from it. At present, it sometimes looks like the exclusive property of two wildly antagonistic camps. The first camp, the analytic school, seem to hope through the analysis of language to analyze philosophy right out of existence and themselves out of jobs. The Continental school, on the other hand, is still concerned with the Big Questions like God and the Meaning of Existence. However, its members have a predilection for all-encompassing book titles like *Being and Nothingness* which can't possibly live up to their advance publicity.

When Psychology broke away from Philosophy in the mid-nineteenth century to set up shop as experimental epistemology, people began to ask whether philosophy might not eventually reduce to the null set. The consensus is now that its best regarded as a method of rational inquiry which can do a useful task in making explicit some of the assumptions inherent in various aspects of structured human activity, or in general as rational inquiry in any field.

One such activity is Science. One task of a philosophy of Science is to compare the stated assumptions about the methodology of science with the reality. Moreover, it can prescribe on the basis of thorough analysis that which is likely to be a worthwhile area and/or method of investigation, and that which isn't. A vast such literature has grown up around Cognitive Science (mainly in the Philosophy of Mind) and we analyze it at the end of this chapter.

However, we're going to find philosophy useful for other reasons as well. Up to Piaget's and Warren McCulloch's (1965) early work, "epistemology" meant quite simply philosophical epistemology. In other words, historically speaking, philosophy is *the* area in which the problem of knowledge has been discussed. Philosophers lacked the experimental tools featured in the other chapters of this book; they had to find some way of systematically appealing to experience.

It's fair to say that they didn't come to many lasting, comprehensive solution to the problem of knowledge. However, we can learn a lot from the clarity with which they discuss issues of perception and cognition. They did manage also to ask the right questions. Having taken a position (e.g. empiricism) on those questions they often found themselves backed into a corner. It is when fighting their corners that they tend to be at their best. We'll see this in particular in Hume's response to Berkeley. One of the really important things about Cognitive Science is its ability, through the current availability of appropriate experimental evidence, to show how all these brilliant minds, though apparently greatly at odds, were in a sense correct.

The path this chapter takes is the following. First of all, we're going to briefly look at the history of Western Philosophical epistemology. Secondly, we're going to regroup by considering at length the central problem treated (i.e. the relationship between mind and world).

Thirdly, we're going to examine the work of existentialist philosophers who had a view of this problem very similar to that emerging in AI.

Finally, we're going to examine current controversies in the philosophy of mind which relate to Cognitive Science.

1.1 The reduced history of Western Philosophy, Part I – The Classical Age

The Reduced Shakespeare Company perform *The Complete Works* (Shakespeare, 1986) in one thrilling evening, culminating in a thirty-second *Hamlet*. The following pages are analogous. We'd better start, as we've a lot to get through.

To make things easier, we'll ignore Oriental thought for the moment. The content of this section, then, is those schools of thought which originated in Greece around the seventh century BC, were preserved through the Dark Ages by the then great civilization of Islam and by Irish monks before coming to a later flowering through the rediscovery by Europeans in Islamic Spain of their own cultural heritage.

The first stirring of philosophical thought around the seventh century BC in Greek culture consisted of an attempt to grasp a single underlying principle which could explain everything manifest. The earliest suggestions for such a principle (from Thales and his followers) were the basic elements as conceived of at the time (earth, air, fire, water) the later suggestion of Herakleitos (or Heraclitus) was change, or fire. Let's note that no distinction was made between the material and the mental, or knowledge and being.

Later came the Pythagorean school, with the first attempt at an abstract description of reality independent of its felt existence. The kind of experience which fueled their work is epitomized by the laws of musical harmony. There is a detected harmonious relationship between strings on an instrument which have certain simple mathematical relationships to each other (e.g. if one string is precisely double the length of another, its pitch is an octave lower). The insight that we can home in on an aspect of reality by manipulation of abstract symbols in this manner is still an exhilarating one.

Let's call Pythagoras and his school the "Neats." The "Scruffs," or Sophists, were in the meantime teaching virtue, as they understood it. With Socrates, the hero of Plato's

dialogues, the Neat/Scruffy division falls apart. To know Plato's world of Ideas is to be virtuous. The Good, True and Beautiful are one.

Plato's schema, depending on one's perspective, is one of the great intellectual constructs and/or one of the great pieces of self-delusion of all time. The world of appearances is flickering shadows on a cave wall. Reality is a set of other-worldly Forms, which objects in this world can somehow participate in or reflect and thus borrow some of their Being. Let's note, parenthetically, that many contemporary mathematicians (e.g. Gödel, Penrose) still take these ideas seriously with respect to mathematical concepts: for example, what in this world is an infinite set?

It is said that everyone is drawn by temperament either to Plato or his pupil Aristotle. One huge issue that puzzled Aristotle is this; how many Forms are there? Is there a Form for a CS text? We see this issue again in AI.

The materialist/dualist war (it has all the characteristics thereof) is essentially part of Plato's heritage. Recent pitched battles: Libet (1985) versus Flanagan (1992); Eccles (1987) versus all comers. If you contrast a world of Ideas with the actual world, the war is inevitable. Aristotle produced a framework in which this type of issue doesn't arise. Substance, he argued, is form plus matter. Consider a biological cell. There are material processes going on by which the cell is a cell (i.e. by which it has its form as a cell). A statue is a more obvious example: the matter of the statue is that by which it has its form. Can we separate the material and mental in the brain in this way?

We consider this issue again presently. For the moment, let's note that Aristotle was an insatiable collector of facts about everything that came across his path. This insistence on observation continued in Greece to Almcaeon and his school, which by the fourth century BC had located thought in the brain, and had at least a sketchy idea of neural functioning. Had a Hellenic Warren McCulloch connected this anatomical work with what was already known about electro-chemical plating, we might have had some very precocious Cognitive Science.

Let's pause for breath for a moment. These themes have emerged:

- The search for a single underlying explanatory principle for all that is.
- The idea that abstract operations on symbols can inform about an external reality to which these symbols point. (If we incarnate these symbols in computer programs, we get what's called the Physical Symbols Systems Hypothesis (PSSH).
- A notion that substance can be divided into form and matter.

Let's again note that Philosophy was, up to this point, also the activities which we call Science, Politics and Theology. It has lost a lot of capital since then.

Had Greek thought maintained this breath-taking rate of progress, there would be little for us to do. We haven't touched on the advances in Logic, Mathematics and Politics which occurred. However, as has been mentioned, the works of Plato and Aristotle were lost to the Western world during the dark ages. Before we fast-forward two millennia, let's note one speculation of St Augustine, Bishop of Hippo in North Africa. Words name objects, and children learn language by correlating the word and

its object. We're noting this point because it's (at best) incomplete, both as a theory of linguistics and developmental psycholinguistics.

1.1.1 Scholasticism and the first stirrings of Modernity – Thomas Aquinas

The reduced history of Philosophy would normally skip the four-hundred years between Aquinas and Descartes. This is particularly the case because Aquinas is normally identified as the foremost defender of the Roman Catholic faith. In turn, this activity may seem to involve aiding particularly nasty South American dictators while condemning the sexual act in all its manifestations.

In fact, Aquinas is relatively blameless on these points. He is important to Cognitive Science for two reasons. First, he provides the first great medieval treatment and development of classical philosophy. Secondly, he and his modern "Thomist" followers (e.g. Lonergan, 1958) have much to say on the act of Understanding.

Thomas Aquinas joined the Dominicans against his father's wishes, and read Aristotle contrary to the stated wishes of his contemporary church. He seems to have suffered from bulimia. Eventually, a large piece had to be cut out of the table so he could sit at it!

His first great contribution to philosophy is on ontology i.e. the problem of Being (what is), what different types of Beings there are. This problem manifests itself as the mind/body problem in CS. Aquinas's solution is worth looking at for this reason.

Aristotle had no distinct concept of existence to complement his notion of substance. Aquinas, in common with philosophers of his time, attributed different vital principles of existence to beings at different levels of evolution. For example, a tree had a vegetative "soul." This is not the main thrust of his argument: however, let's note that these kind of notions are re-entering biology under the heading of "entelechy," and they cast welcome mud into the deceptively clear waters of the monism/dualism debate.

Aquinas asks us to look at a person or anything which exists. He distinguishes the following:

1. That which is.
2. Its existence, which it possesses by virtue of an act of existence.
3. Its form, which it possesses by organizational patterns in its matter.

Thus we have a form/matter distinction as well as an issue of the potential for existence being fulfilled by an act of existence. Instead of the Cartesian mind/matter dualism we are going to confront later we now have a trio of substance, act and potency.

Moreover, the notion of substance allows us to speak of the form, as distinct from matter, of all biological entities, including mind. Much effort has been expanded on attempting to show that either monism or dualism is correct (e.g. Libet, 1979, versus Churchland, 1988). The position of this book is that the ontological issue is a great deal more complicated.

Thomism has much to say about Understanding. For its followers, understanding is about more than mere cognition: it quickly, in turn, structures one's ethical concept, then one's concept of God. Thomism sharply distinguishes understanding, which has as its object an idea, from imagination, sensation, perception etc. It is from analysis of the act of Understanding that the whole of Thomist philosophy gets its main thrust.

And so on to modern Thomists. The major figure is Bernard Lonergan (1958) who takes on board a great deal of modern mathematical science. He begins his major work, Insight, with an account of Archimedes in the bath. Let's examine this story.

King Hiero of Syracuse had had a crown with much filigree work fashioned, and he doubted whether it was actually made of gold (as mentioned above, electroplating was already an established technique). To establish that it was, it would be necessary to find the precise volume of the crown with all its filigree, an unenviable task for Archimedes. Disconsolate, he took a bath. As he stepped into the water, he noticed the water level rising. At that moment, he realized several different points:

1. The volume of water displaced was equal to the volume of his body.
2. Therefore, he now had a way of measuring the crown's volume.
3. He could remain on good terms with the king.

He simultaneously forgot several other things about social decorum and ran naked through the streets for a while before remembering them again. Before discussing Lonergan's analysis of the Eureka moment, I want to emphasize what Archimedes forgot, as well as the fact that the insight arose as a result of his experience of his body. Thomists, good Catholics as they are, sometimes tend to ignore the body.

Lonergan claims that insight supplies to key to cognition. He says it has five characteristics:

1. It comes as a release to a period of inquiry.
2. It comes suddenly and unexpectedly.
3. It is largely a function of conditions both external and internal.
4. It has both abstract and concrete aspects.
5. It becomes part of the structure of one' s mind.

That last point in particular is extremely important for CS. It's now accepted that we can't develop AI systems without a valid theory of cognition and that we can't discuss cognition except with respect to its development. What this analysis of insight informs us is that one central aspect of cognitive development is Eureka moments.

Understanding for the Thomists is mainly an unembodied act. That is where their system falls down for CS purposes. However, they certainly treat the ontological problem much better than Descartes and the scope of their thought is impressively wide.

1.1.2 Descartes: the first Modern?

In seventeenth century France, it was unusual to stay in bed until 11am in order to think. That being Descartes's wont, he moved to Amsterdam where, as he explained, people were too busy making money to notice a philosopher in their midst.

It is hard to overstate Descartes's influence on the sciences of mind. He wrote also on physics and famously invented Cartesian coordinates and other mathematical techniques. At one point, he turned his attention to the "robots" in the **Tuileries** gardens which operated by hydraulics: water directed through the limbs causing them to move. The Human nerve passageways seemed similar: could it be that their functioning was identical?

In the meantime, Descartes was also considering how to root a systematic philosophy. He could doubt everything, he decided, except his own existence. He could conclude the latter by the fact that he could think: *cogito, ergo sum*. Moreover, this "I" who thought had to be a thinking thing (*res cogitans*) as distinct from the rest of nature, which merely was extended in space *(res extensa*). *Res cogitans* interacted with the world through the pineal gland in the brain by releasing the watery "humors" in the nerves.

Thus, unlike Aquinas, Descartes has a very sharp spirit/matter distinction which lumps all aspects of mind under "spirit." (Even today, the French "Esprit" confusingly connotes both mind and spirit, sometimes in technical CS texts). He then went on to ask how this soul could get to know about the external world. So far, we've got a theory of its action.

Its perception, Descartes argued, was due to abstract representations of the external world being served up by the senses. These could be just encodings, rather than strict models of the objects they represented. So far, if we substitute the Central Processing Unit of a computer for the Cartesian Soul, we have a precise analogy to the AI metaphor.

The analogy cuts even deeper for the whole of the methodology of CS. That we could usefully discuss the models of objects without knowing anything about their essence is one consequence. To continue this point, we can exclude all external factors except as represented to ourselves, and by studying the action of our minds in this manner, we can know all there is to know about the world. This tenet is called *methodological solipsism*.

These points have a familiar ring precisely because Descartes' influence has been so massive. In fact, it is unlikely that the founders of AI were even aware of how profoundly they were influenced by them. In this light, we can look on AI as a working-through of the Cartesian program in real, implemented computer systems. Looked at in this way, that program has been an interesting failure in ways which we consider in chapter 5.

1.1.3 British Empiricism

The Cartesian program forces one to focus on the Soul (or homunculus) hovering around the Pineal gland and obtaining knowledge through symbolic operation. This latter symbolic point makes Descartes fit into the rationalist tradition. The British empiricist school is essentially a set of replies to Descartes.

Hobbes was a contemporary of Descartes who became acquainted with his work during his several periods of political exile in France. Unlike Descartes, he stressed the primacy of empirical data, i.e. sensations. How else could we obtain knowledge about

things in the world? Moreover, concepts were not “naturally occurring kinds” but simply the result of the process of naming (this idea was called nominalism). There is a certain almost attractive bloody-mindedness about Hobbes. He seems also to have been an atheist, whose political views (in his classic *Leviathan*) allowed him to support any political system as long as it used force properly.

What we’re concerned with here, however, is the epistemological correctness of Hobbe’s work and its relation to CS. In the debate between the rationalist Descartes and empiricist Hobbes, we see prefigured a debate which currently rages in AI. It hinges on the question as to what extent we can or should try and express the content of the domain on which a computer system for AI is to work in terms of explicit symbols.

Hobbe’s follower John Locke adds another plank to empiricism. He insisted that the child’s mind at birth is a blank slate (Latin: *tabula rasa*) on which the world impressed itself. The full British empiricist view of mind has one T-junction to navigate before coming to its conclusion in David Hume’s work.

Though self-consciously Irish (he once replied to an Englishman “We Irish think otherwise”), George Berkeley has suffered the lot of any successful Gael in being adopted by the British. In between his educational work in the USA, which resulted in a University in his name, and his duties as the Bishop of Cloyne, he somehow got the time to write his *Principles of Human Knowledge* and other philosophical works.

As we see below, it is by no means unusual for a philosophical viewpoint, followed consistently to its conclusion, to engender its antithesis as a logical consequence. Berkeley took the British empiricist critique of Descartes on board and followed its line of argument to an unforeseen destination.

Consider a household chair. As we move around it, our perspective continually changes and the image on our retinas alters correspondingly. How do we manage to identify it as the same object? AI vision work has demonstrated that it is excruciatingly difficult to continually update the image and compare it with a stored representation (Note that this is one manifestation of the “Frame problem.”) Berkeley argued that, since all that the empiricist view of mind allowed was sense-data from the chair, we are compelled to appeal to a notion like the material substance of the chair. But where was this material substance, which was required by theories such as Locke’s? It was, according to Berkeley, a nonsensical idea.

Berkeley’s statement of the Frame problem is brilliant, and a paradigmatic example of what we can learn from philosophical epistemologists’ acute analysis of perception. However, his solutions are not quite as good, and left him vulnerable to the attack of the Scot David Hume (another Brit, of course!) which we note presently. Berkeley ended by appealing to notions like the “Soul” to unify the various appearances of the chair, and to God to somehow keep in existence things which were not being perceived (*esse, sed non percipi*).

Hume, whose early career had a shaky start (involving, for example, using a pseudonym to give a rave review to one of his own books), eventually ended up working for the English embassy in Paris. Let’s start with a thought experiment to give a flavour of Hume’s system. OK, let’s look within (introspect) for Berkeley’s soul.

Two things will happen: if we divide ourselves into subject and object, and try to find the soul as an object, the regress is infinite. Alternatively, if we try and grasp the essence of the soul by subtracting all the mental contents which life impresses on us, we end up with the null set. Hume's conclusion was that Berkeley's Soul did not and could not exist. (We review these arguments below in the discussion of Merleau-Ponty).

Hume is a thoroughgoing empiricist, and he's now lost his Soul. It is at this point that he introduces the main themes of what was to become the standard British empiricist view of mind. Mind, he insisted, was a flux of ideas and sensations which succeeded each other in a manner outside our control. Empiricism, in its later formulation (Hume, 1777) stated that ideas followed in accordance with the laws of similarity (i.e. they were alike), contiguity (i.e. they were first experienced together) or contrast.

We've now come to the culmination of the empiricist reply to Descartes. As noted, the tension between rationalism and empiricism presages the central issue in current AI (i.e. the use of explicit symbols). Our view of mind has, it's fair to say, become somewhat simplified.

1.1.4 Immanuel Kant

With Kant, we get the beginnings of a view of mind which is specific enough in its details to be computationally useful and which does justice to the wealth of philosophical debate in the context of which it was put forward. Kant has had more explicit influence on CS than any other philosopher. It is arguable, however, that the influence of Descartes has been so all-pervading that most non-philosophers default to a Cartesian mindset.

Kant spent all his life around Königsberg, which was at that time in East Prussia. He ended his days by far the most famous phenomenon in an undistinguished town. So regular did his days eventually become that the town's populace began to set their watches by him. "Here comes Herr Kant – it must be 4.03pm!" It was still regular practice for philosophers to hold forth on various subjects. Consequently, Kant wrote on astronomy as well as epistemology and proposed correctly that galaxies were formed by gravitational attraction.

Kant's *Critique of Pure Reason* is perhaps the most important epistemological text since Aristotle. We need to consider what his intellectual motives were to consider his work properly.

Hume, we have seen, was a thoroughgoing empiricist. The shock which Hume's theory of mind still produces was, according to Kant himself, enough to wake him "from his dogmatic slumbers." Hume's Mind is a wild succession of ideas and sensations replacing each other according to laws of association. Yet there is definite structure in how all we humans perceive the world and communicate to each other about it: we have concepts of number, self, causality, logic etc.

Let's look at a few of these concepts. Modus Ponens in Logic (the "positing" mode) has this structure:

If P then Q
P
Therefore Q

For example:

If it's May, the French Tennis Open must be on soon.
It's May
Therefore The French Open will be on soon (check in your TV Guide).

Let's note that Modus Ponens doesn't allow us any choice about Q once P is established. Analogously, we tend to infer that A causes B if event A always precedes event B. Thus, our notion of causality is similarly deeply-entrenched.

It might be hypothesized that knowledge of Modus Ponens is a generalization from experience. Kant countered that this wasn't enough: from experience, we might gather that Q is *probably* true having established P, but not *necessarily* true. An analogous situation exists for Causality, and much of arithmetic.

So where do we get these concepts if they can't be inferred from experience? Well, maybe they're purely internal structures in some kind of Cartesian homunculus. But if that's so, how is it that they are so effective when dealing with the world? (We'll come across these arguments again in the section below on Objectivity).

Kant's answer is that such notions as number, self (see chapter 8), causality and substance (about which Berkeley was so contemptuous) were not wholly inside the mind, or wholly abstractions from experience. He argued that there was a third force. This third force is the manner in which Mind must necessarily structure its experience. These structures he called "Categories" and they included such entities as Modus Ponens, etc. This is Kant's conceptual Copernican revolution and it has consequences for the methodology we use for Cognitive Science. He argued that by a method called transcendental deduction, we could arrive at conclusions concerning the nature of these categories. In the chapter on psychology, we note an experiment where the concept of causality is shown to be "built in" as Kant pointed out. Not that Kant would have approved. He was notoriously anti-psychology (as a science), stressing that it could never achieve quantification of its observations. Transcendental deduction can involve quite simply noting the performance of experimental subjects on a given task, tweaking the conditions of the task to try and isolate the category that we're looking for, and making the necessary deductions.

There is a final corner to be navigated in our account of Kant. The essence of categories is in fact more abstract than homely notions like number. In fact, "quantity," comprising unity, plurality and totality (Copleston, 1962), would be the category corresponding to number. On the one hand, then, we have these abstract categories, and on the other sensory experiences like "yellow" and "loud." Obviously, we need a connecting layer. This layer must comprise experience which is sufficiently sensory to allow ready connection with the world, and sufficiently abstract to allow relation to these fixed categories. Kant posited a notion of schemata which is very similar to

Piaget's (see chapter 2) to fit into this space. The schema for quantity, i.e. the link from quantity to sensory experience, is number. It is through number that quantity and world interact. Similarly, it is through the schema of permanence in time that the category incorporating causality comes into play.

We need not concern ourselves further here with the labyrinthine world of Kantian Metaphysics. (His project of founding a moral philosophy on epistemology is evaluated in the companion volume to this one). The crucial point from Kant is that we now have the third force which we noted above, i.e. a notion that there are systematic rules by which Mind must structure its experience. We can attempt to isolate these rules by appropriate psychology experiments or we can try and build them into our AI programs. We are not even particularly concerned that we sometimes (if very rarely) have to abandon notions like Causality in Quantum Mechanics, or Euclidean Geometry in General Relativity. These Categories work for everyday experience.

Another useful path would seem to be to study how children develop these Categories and schemata to their full adult maturity. If we can show that this development has many of the characteristics of biological adaptation, then we've really got something. Jean Piaget's work, which we discuss in the next chapter, attempts to do this.

We're beginning to talk biology, but we've forgotten the body. This omission we will redress in the discussion of modern philosophy. For the moment, we're going to take a well-deserved breather. We need to review where we've been so far. Let's do this review in the context of a general discussion of how mind relates to the external world.

1.2 Mind and World, Part I – The problem of objectivity

So far, we've had a package tour by bus of the main philosophical schools. If this is Tuesday, it must be empiricism. Well, we liked some of those places, and we'd love to see them again.

If we start considering the problem of Objectivity in the abstract i.e. the extent to which we can have correct knowledge of the external world, we have the excuse we needed to revisit those cathedrals of thought.

We're working under a single premise: there is an "out there" (the world), and an "in here" (mind). It's like fencing: he's got a sword, you've got a sword and the only rule is that you win if you hit him better than he hits you. We're going to find reasons in section 4 of this chapter for nuancing even this rule.

So, how does the in here (mind) relate to the out there (world)? There seems to be a choice to be made between two primary options: idealism (e.g. Platonism) and realism (e.g. ecological realism). The former school tells us that mind is informed by the action of ghostly external entities called "ideas." The latter tells us that the external world fully forms our mental contents.

Given the rules of our game, we can't actually refute a determined idealist! He's going to argue that all his experience, including his experience of your arguments against him, is of (Platonic-type) Ideas. We can force him to defend an apparently absurd position by asking him whether there is a Platonic Idea corresponding to, for example, the middle of the NFL season, but we can't refute him.

Realists, on the contrary, say that all mental contents explicitly reflect something external. We've already noted Berkeley moving around a chair and getting different perspectives: for realists, all the perspectives are objective properties of the chair. They have problems with the fact that we can create images of impossible things like Unicorns, but that doesn't overly concern a really determined Realist. As in life, the hard-core realists are the really crazy ones.

Let's start focusing on the development of this knowledge. Rationalists insist that it's developed by some kind of structured mental operations: empiricists we've seen insisting that it's sense-data. Moreover, we've also seen that these schools take opposing views on what concepts are: for conceptualist rationalists, concepts reflect some naturally-occurring divisions of Reality. For nominalist empiricists, on the other hand, concepts are just names.

These arguments rage through the centuries. They seem to lack any neat resolution of any sort. You're a rationalist? You've come to a new conclusion through reasoning? But what new empirical fact did you notice to provoke this new conclusion?

Up to recently (e.g. Ayer, 1982, p. 3) it was thought that perhaps philosophy might settle these issues (and others like innatism versus empiricism) using its own techniques. It has long given up trying to produce a worldview by starting with isolated reflection and building up to an encompassing theory of Life, the Universe and Everything. The chances are, however, that even its attempts to resolve issues like rationalism versus empiricism on its own are bound to be fruitless.

For a start, stating these schools of thought as antagonistic philosophical positions and trying to resolve them in some way may be a pointless exercise. We've seen that this kind of antagonism can yield breath-taking creativity like Berkeley's, but it's not going to give us the type of principles we need correctly to engineer AI systems.

Secondly, it's possible that these questions simply can't be answered in philosophical grounds alone: we need also to be able to experiment. This is the primary aim of Cognitive Science as experimental epistemology. We're going to see, for example, psychological evidence on the innatism issue in the next chapter.

More interestingly we're going to find that all these philosophical schools seem correct in their own ways. For example, we find that different AI systems working well on different tasks seem to be implicitly based on different philosophical schools.

Let's take the apparently simple task of trying to get a robot to move around a room, avoiding obstacles and picking up cans. The rationalist school would suggest that the way to do this is to:

1. Internally represent the room explicitly.
2. Update this model as changes occur.
3. If asked to perform an action, refer to this model.

Unfortunately, this approach does not work. We discuss why in more detail in chapter 5: for the moment, let's note that an empiricist, situated approach seems to work better. Contrariwise, empiricism has problems with explicitly symbolic behaviour like mathematical reasoning, where rationalism shines. When it comes to infinite sets even idealism has its day.

One of the main themes of this book, as was noted in the introduction, is that these historically intractable problems can be greatly elucidated by Cognitive Science. Moreover, the apparently contrasting (dichotomous) schools are seen to reflect different maximally effective modes of cognition in different types of domain.

Where does this leave philosophy? It is best thought of in this context perhaps as the study of evidence, in the manner of a legal trial. New techniques like genetic fingerprinting may be developed which upset a previous apparently safe verdict, just as a psychological experiment may upset a previously sure "fact." However, philosophy has much to contribute both in the rigor of the argument which it demands and the imaginative scope of the philosophers who are still willing to go beyond science.

The geniuses of the imagination and rigor are in modern terms, respectively, the Continental and analytic schools. Let's pay them a visit.

1.3 The reduced history of Philosophy, Part II – The twentieth century

1.3.1 The Continental School

The title granted to mainland European thought in the English-speaking world is reminiscent of the famous English newspaper headline "Fog in Channel: Continent isolated." The types of problems dealt with by philosophers such as Heidegger and Merleau-Ponty, whom we will consider as the best examples of Continental philosophy (qua epistemology) tended to be quite different to those dealt with in the Anglo-American world. In particular, the mainland Europeans insisted that there had to be more to philosophy than analysis of language, of whatever degree of precision. For them, philosophy was to consider essential issues of our existence as thinking beings in the world. Moreover, they refrained in their analysis from separating the *res cogitans* from the *res extensa* mind from world. The primary experience was to be considered as Being-in-the-world, which Heidegger called "Dasein" (being there). The difference between Heidegger and Kant is possibly best reflected by their attitudes to proving the existence of the external world. For Kant, the scandal of philosophy is its inability to provide this proof: for Heidegger, it is that it should feel itself impelled to do so.

In a sense, these philosophers are heirs to Thales and his school in their concern with the general problem of Being. Their refusal to adopt either monism or dualism is absolutely categorical: man is a unity of both psyche and body.

Heidegger was the first philosopher to truly emphasize man's "mundanity," that his existence can be considered only with respect to a changing, conditional world. Nor can we properly consider mental structures without respect to the context in which they are being used: the word Heidegger uses for his is "thrownness." This latter term has been imported into AI literature (particularly by Terry Winograd: see chapter 5) as "situatedness."

With Merleau-Ponty, we get an enormous emphasis on "embodiment," i.e. the fact that human cognition relies heavily on the body. Whereas Heidegger has often been reproached both for (Ahem!) German chauvinistic sympathies and linguistic obscurity, Merleau-Ponty has managed to preserve much more of his reputation.

His working-through of the embodiment precept is meticulous in its detail. He realizes that there is a great danger of falling into old habits of linguistic materialism and dualism and he steadfastly avoids them. Merleau-Ponty's work is the nearest approach we have to a coherent basis for a full analysis of situated, embodied cognition, so we'll study it in some detail. Yes, that is him on the cover page of this chapter!

1.3.2 Maurice Merleau-Ponty

Let's start again with that crucial point about "mundanity." Merleau-Ponty would stress that if we start by separating the knower from the known, there is no way of putting them back together again. There has to be some alternative form of description which can omit this distinction. Merleau-Ponty also wants to nuance that in here/out there (subject/object) distinction which we held onto throughout our discussion of Objectivity. He argues that our experience of the body runs counter to this distinction. At times, there is no question that the body is subject: if I feel pain, this body is me. Let's call this "egocentric" cognition. However, if I am about to ascend in a lift which has a maximum capacity of 12 and there already is that number inside, the body is an object. In like fashion, we can call this "intersubjective" cognition.

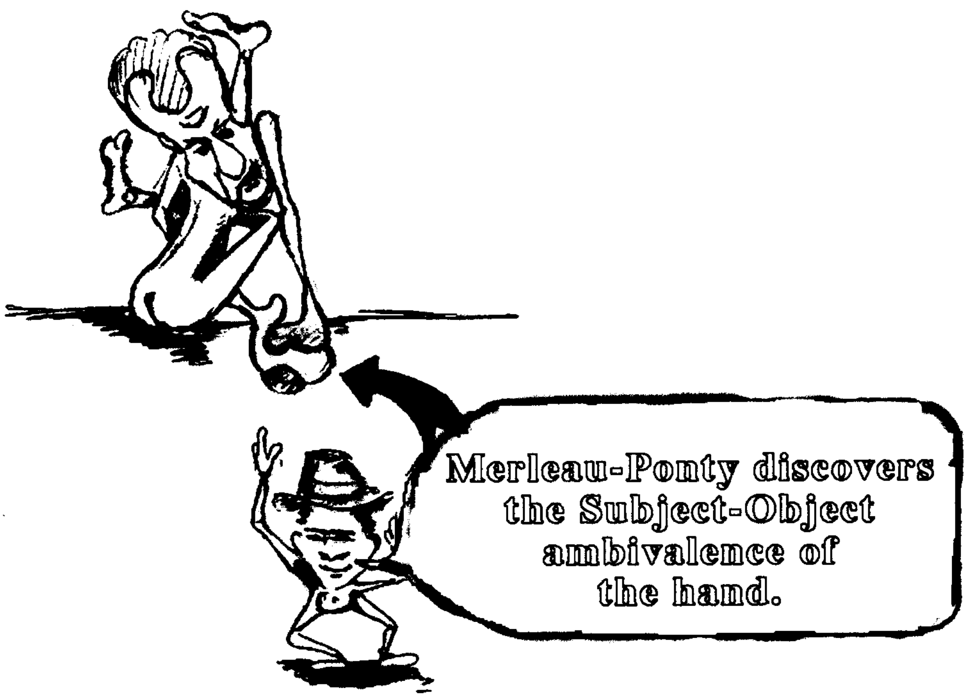


Figure 1.2

Let's do a simple experiment: grasp your left forearm with your right hand. Then direct your awareness to the sensation of pressure on your left forearm. The movement here is from feeling this forearm as an object to feeling it as a subject. As diagrams 1.2 and 1.3 show, it's possible to tie yourself up in knots a little bit here!

Merleau-Ponty uses the term "the body-subject" to express the embodied experience of reality we all share. It is a little bit confusing, in that the body can also be object. We're a little closer to the reality of what he meant if we use the translation of the appropriate French term, i.e. "incarnated mind."

A lot of his work is a brilliantly detailed analysis of the flow of information between body-subject and world as we live. He argues that there is a dialectical relationship between the world and self as we impose richer and richer meanings on objects as our consciousness develops. Conversely, these objects are the necessary context for this development. He has set himself an enormously hard task, then. It's no less than the analysis of what our relationship with the world is like at the level beneath which we usually actually start to reflect on the world. He insists that this relationship is already full of meanings which we may not even be conscious of. Whether these meanings are genetically given is not the concern here.

What is genetically given, he insists, is a notion of 3-dimensional space. (We'll note that J J Gibson's notion of "affordance" is very close to Merleau-Ponty here). He argues this point against the theorists of this time who would have insisted that depth perception required touch and other physical experiences. Recent psychological experiments seem to vindicate him on this point (Streri and Lécuyer, 1992).

By a series of paradoxes, he argues also that we are plunged from the start in a world which involves the active existence of other people. He uses the existentialist distinction between *en-soi* (the being of objects) and *pour-soi* (the being of subjects) to build the crucial paradox. Other people must be both *pour-soi* and *en-soi*. If we deny the primary reality of the intersubjective world, we are faced with a vertiginous realization. Other people are *en-soi* for us, as our consciousness fills to encompass the world. Yet we must be objects for them, as their consciousness likewise swells. The solution, he argues, must be that the intersubjective world is primary in even the first act of consciousness.

A notion of Being involving 3-D space, objects with meanings attached and the existence of others is therefore primary. It is now that we begin to notice a few problems with Merleau-Ponty's work. His analysis of the reality underlying perception is superb, but where do the symbols we use in e.g. language and math come in? For him, language also is an egocentric phenomenon. (It also comprises everything worth mentioning about thought, which we discuss in chapter 3 in the context of Chomsky's work.) How can it relate to the intersubjective mode of the body-subject's existence? We'll find the perception/symbol problem coming up again in discussion of Mobotics in chapter 5. Piaget's work complements Merleau-Ponty's well with respect to the crucial problem of moving from egocentric to intersubjective modes of existence. In fact, both are also very compatible with the trend to root mind in biologically-based interactions with an environment. Development of Mind is describable through a process called "equilibration." We examine this point at length in chapter 2.

The themes of mundanity, embodiment and thrownness which we've introduced are developed greatly in chapter 5. These are indeed the new dogmas of AI. It has thus been of extreme importance to analyze the concepts of the first philosopher to work them through properly. Moreover, Merleau-Ponty in particular makes psychological statements which are scientific in essence e.g. his hypothesis about 3-D vision. With him we've come to the point at which philosophy has become specific enough to be experimentally testable.

1.3.3 The Analytic School: The Campaign to clean up Philosophy

It's possible, of course, that we've been wasting our time discussing the history of philosophy in the first place. The analytic school claims that a great deal of the apparent "problems" of philosophy are quite simply puzzles thrown up either by inadequate scientific knowledge or abuse of language. Take the mind-body problem, which we discuss presently. It seems initially remarkable that one can "internally" formulate a desire like "I want to go to Portugal" and on this basis perform the requisite "external" observable acts (buying a ticket, packing the bags…) which fulfil this desire.

However, this internal/external distinction could surrender to science. Let's imagine that our brain imaging techniques (chapter 4) become good enough to plot all firings of specific brain cells (neurons). We could, theoretically at least, establish characteristic patterns of firing which indicate a desire in me to go warm climes, further specify those for Portugal, and so on. Now both the apparently internal desires and external acts are within the domain of the same kind of observational analysis.

In order to introduce the technique of linguistic analysis, I'm going to take what is in this chapter an unusual step: I'm going to quote somebody. Heidegger won the linguistic obscurity Olympics with statements such as: "Nihilation is neither an annihilation of what is, nor does it spring from negation… Nothing annihilates itself" (Passmore, 1966). The standard analytic's reply to this statement is that Heidegger has made the mistake of assuming that "Nothing" is a name, i.e. that it refers to something. In the most fundamental sense of this hackneyed phrase, Heidegger's statement is nonsense and means nothing. Similarly terms like "Being," "Consciousness," etc, must now be viewed with some suspicion.

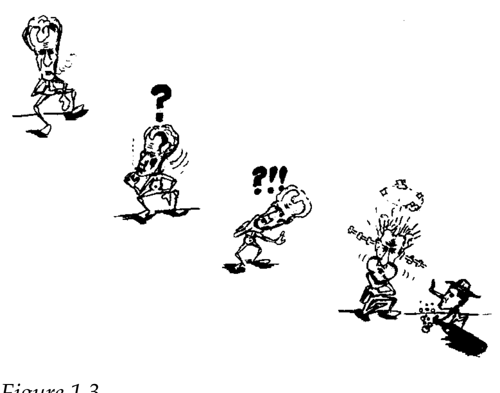


Figure 1.3

The campaign to clean up Philosophy had its initial meetings in post World War I Vienna. It is reasonable to expect that all knowledge is going to be expressed in Language. Consequently, the focus of the "Vienna Circle" was language and its abuses.

Though only a tangent to the circle, Ludwig Wittgenstein produced the fullest

deconstruction of language. We discuss him at length in his role as an AI skeptic in chapter 5. For the moment, it suffices to note that Wittgenstein's (1922) first project was to invent techniques to analyze the logical structure of language. He, and others like Schlick, Carnap and Neurath who attempted the same project, assumed that this analysis would bottom out on "atomic propositions" which referred to simple objects (*Tatsachen*) in the world (see diagrams 1.4 and 1.5). The world could be described completely in terms of *Sachverhalten* (states of affairs) which ultimately were just regular combinations of *Tatsachen*.

It is a lovely story and, with the correct tune, would make a great ballad. Unfortunately, there are at least two major problems with it. The first is the nature of these atomic propositions. Associated with this first problem is the issue of analysis itself. Wittgenstein gives no fully worked-through example of a sentence being mapped to atomic propositions.

Nor does he give any examples of the second issue, i.e. how to map these atomic propositions onto logical atoms. His original conjecture was that the atomic propositions and logical atoms were the same for everybody. However, the mapping from one to the other was done by an idiosyncratic "private language," unique to each person. The parallel with AI is so inviting that I'm going to pre-empt some of the discussion in chapter 5 by accepting the invitation. We can usefully think of this private language as the instruction set of a computer. Two computers with different instruction sets might run the same program, with exactly the same input-output behaviour, but with a completely different set of machine code commands (the lines of 1s and 0s in the diagram 1.4) being initiated in each case.

The first problem about atomic propositions is reminiscent of the ancient problems confronting Platonists: how many of these ideal Forms/atomic propositions were there, what exactly were they, and how did they interact with Reality? (We'll see these issues recurring in the chapter 5 discussion of Knowledge-Based Natural Language Processing). The second problem is perhaps an even deeper one and it behooves us to give it some attention. We'll note that Neurath's notion of the "Protocol Sentence" ran straight bang into the same wall.

Any kind of positing of internal processing is going to run into the second problem. Essentially, how can any *private* language refer? The answer Wittgenstein gave is that it's impossible. However, AI systems based on this type of conceptual architecture seem to function at least in some domains. These domains are usually essentially static and admit of a parsimonious symbolic description. There must be some sense in which private languages are valid.

Wittgenstein (1967) begins his rebuttal of private languages with the quote from St Augustine, referred to above, concerning how words refer and how children learn language. Yet the fact is that some words do refer (book) and children can learn associating the sound and the object in these cases. Perhaps there are a multiplicity of different ways by which words can refer? We return to this point in chapter 5.

We're anticipating a lot at this stage, so let's rewind a little. The primary aim of analytic philosophy is to restore clarity in language. Having done this, it is expected

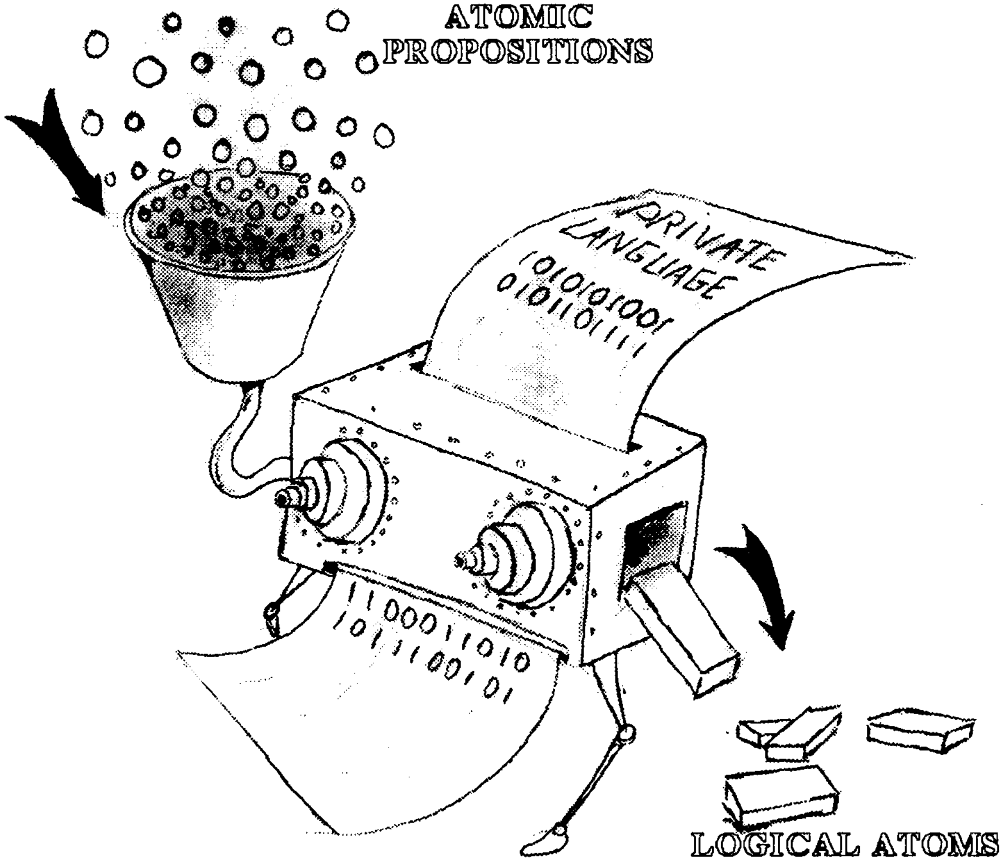


Figure 1.4

that many apparent problems in philosophy will turn out to be no more than linguistic conundra.

If natural languages like English prove to be hopelessly obscure, well, so much the worse for them. It may be necessary to distort them to create "Protocol sentences" of absolute clarity, or even to invent a logically perfect new language. In any event, the truths to be expressed through the medium of this language are all scientific truths. Moreover, Science is a continuum from the hard sciences like physics on the right to the social and behavioural sciences (including psychology) on the left. The question arises as to how we can quantify mental life so as to admit of this type of description. We discussed one technique for doing this above, i.e. examining the overt data associated with the wish to go to Portugal.

One key concept of the Vienna Circle was the Verification Principle. The scientific value of a proposition was identical with the mechanisms by which it could be

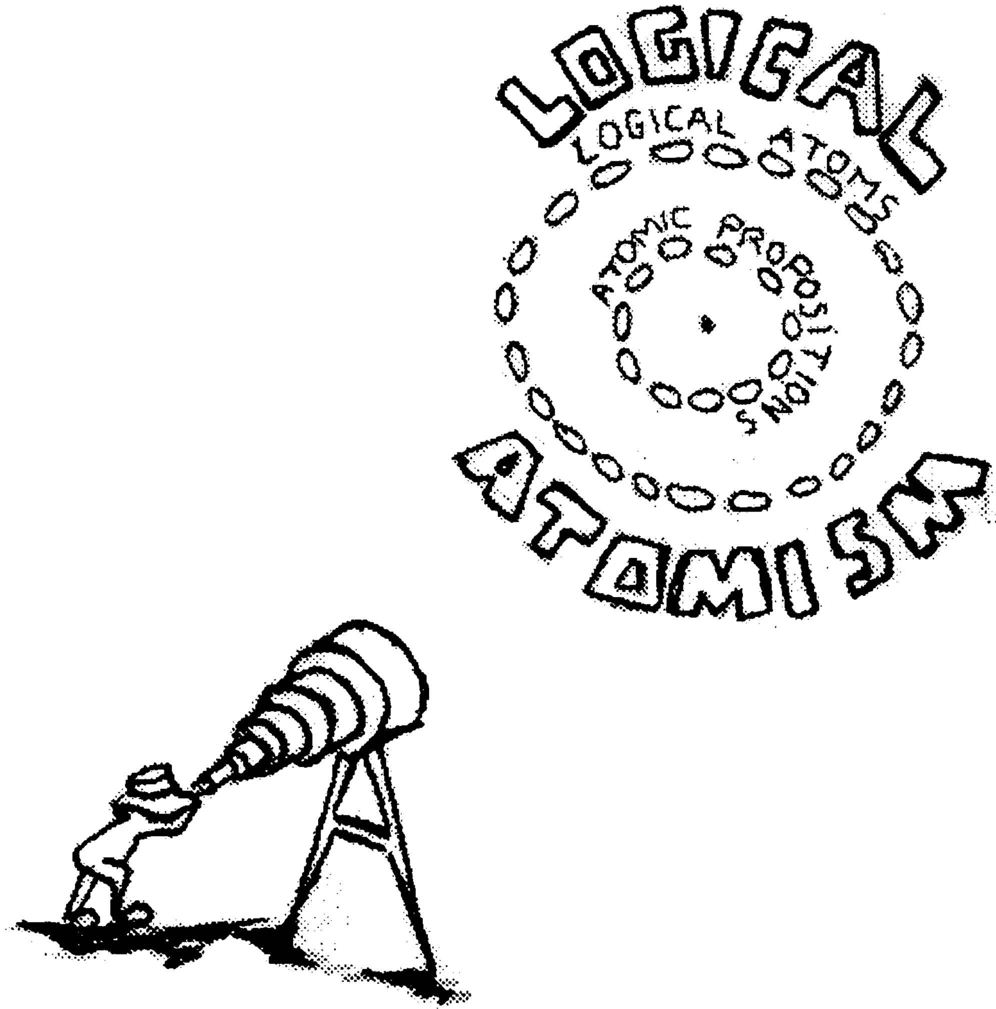


Figure 1.5

verified. "I am hungry" could potentially be verified with respect to overt bodily activities. "God exists" can't be verified like that, and so has no scientific value. Likewise, statements similar to "I feel a shadow has passed between us in this relationship" would have difficulty being verified. Consequently, and here we come to a really important point, a great deal of real mental life gets jettisoned with acceptance of the Verification principle, along with much metaphysics and theology.

As we're going to see later, semantics in computational linguistics (elsewhere, it becomes very obscure indeed what precisely it is about, or what possible relationship to the world it envisages for symbols) is often treated as the study of meaning, usually

including how groups of propositions can acquire meaning through their logical combination. If the ideal language could be correctly designed, we could abandon semantics completely. The notion of "logical combination" would be superfluous. The semantic content of sentences could be obtained on the basis of syntax alone, i.e. on the basis of the grammar of the language. (Chapter 3 includes an analysis of the appropriateness of the syntax/semantics distinction.)

However, we've seen that all attempts to create such a language failed. Even without the private language argument, the failure of Wittgenstein, Neurath, Schlick and Carnap to come up with a single atomic proposition and/or logical atom was impressive. Moreover, another issue presented itself: what were the ultimate facts? Were they sense-data, as Neurath thought, or something a little more ineffable as Wittgenstein postulated?

All these arguments are extremely relevant to contemporary debate in Cognitive Science. We're going to review several attempts (such as Churchland's) to reform our view of mind as radically as the Logical Positivists. It's worth pointing out one final paradox here: the Vienna Circle, while apparently radically materialist, ends up flirting with dualism. This Ideal Language contains all the Truth, mental terms and meaning. It is to be distinguished absolutely from discourse or activity of any other kind. The old Cartesian mind/matter distinction has sneaked up on us!

The English philosopher Gilbert Ryle is our last stop on the journey to the present day. His analysis focused on analysis akin to our Portugal example, but without even the equipment to do brain scans. Consequently, on the one hand we simply have the English sentence "I wish to go to Portugal." On the other, we have the overt behaviour in buying the ticket, etc. Ryle's "philosophical behaviourism" does a valuable service by showing that a certain subset of mental life can usefully be described in this manner. However, his account of activities like memory and perception is inadequate.

Cognitive Science could play an enormous role in the philosophy of mind. The logical positivists and philosophical behaviourists were not being mischievous or deliberately obtuse in trying to quantify mental activity as they did. Rather, they were struggling sincerely with the problem of how to remain rigorously scientific while talking about mental life. Cognitive Science has afforded new opportunities for doing that. In the first place, computer programs offered a practical hands-on example of how apparently mental, previously fugitive conceptual entities could be implemented.

In fact, a paradoxical situation arose with the advent of programs which performed tasks like "reasoning" about chemical structure. The AI scientists who designed the programs felt comfortable about using words like "memory," "thought," and so on, while talking about their programs. Psychologists of the same period, who were steeped in philosophical behaviourism, were forced to eschew such words while talking about humans! One of the enormous advances due to Cognitive Science is that the scope of Mind, as scientifically studied, is now both our conscious experience and unconscious processes which affect our behaviour. We discuss this in considerably greater detail below. For the moment, let's leave the Reduced History of Philosophy with one final thought. The dialogue between science and philosophy is more complicated than may immediately seem the case. At first blush, it may seem that

science eats into domains originally covered by philosophy like physics and biology, turning them from objects of speculation into hard-edged sciences based on observation and experiment. By this token, it seemed at the early part of this century that Science would encroach on the area called "mental life" in the same way. Quite the contrary has occurred: instead of having a science which linked verbal behaviour to overt acts in order to explain, for example, intent, we have one which has a vastly richer store of valid data and method. Exactly, what these are is the topic of the next section.

1.4 The philosophy of Cognitive Science

Contrary to the usual practice of CS as it addresses this area, I deliberately emphasized philosophical epistemology, rather than the philosophy of mind, in the title of this chapter. The latter discipline will not be ignored; we consider it below. However, I consider that is has been on occasion accorded an over-privileged status in the field of CS, at the expense of other disciplines. Its practitioners dominate the agenda of CS in the same sense, for the same reasons, and with much the same degree of benefit as that which occurs when lawyers dominate politics. Experts at debate, they can turn practice into theory, and fact into fiction as their pet procedures dictate.

A good example of this is Fodor's (see below) argument about the non-existence of a knowledge level in cognition. This makes many semanticians and not a few AI workers redundant immediately. The only theory of semantics Fodor will accept is semantic functionalism, originally a behaviourist notion. But wait! Is it not true to say that AI systems which work with what their developers considered a knowledge level actually work reasonably well?

The concerns of the philosophy of mind (best expressed by Roberto Casati as the attempt to give a unified philosophical account of desire, feeling, belief, awareness, understanding and action which frankly doesn't leave much for the rest of us to do) are absolutist in a field where the set of base concepts must be capable of radical change due to empirical findings and cross-disciplinary fertilization. On a methodological level, the philosophy of mind should feel itself obliged no less than other fields to propose creative cross-disciplinary syntheses (as indeed Fodor did at one stage). Too often, its mode of argumentation is to follow lines of thought to absurd conclusions (*reductio ad absurdum*) by means, inter alia, of thought-experiments, and then pick through the carnage to find that, say, semantic functionalism or innatism has remained intact (shades of idealism!). Asked to give examples, they can't, but vehemently argue that the conclusion is correct. There must be something wrong.

I believe one of the problems is with the status of the thought-experiment in this field. We are from time to time asked to consider what it would be like to be a brain in a vat, receiving simulated sensory input, to have a precise double (beam me up, Scotty), or to live a completely socially isolated existence. It seems very likely that all of these situations (particularly the first) bear the hallmark of an implicitly Cartesian view of mind, and the arguments gain their impetus from precisely the Cartesian mindset we default to in this culture. Again, we find folk-psychological terms like "believe," "know," "meet in the flesh," mixed in the stew. One of the conclusions of CS, as it

outflanks those who would set its agenda, may be that these situations are non-situated and impossible. I am partly this brain you would place in a vat, but also partly this body, and I am interdefined in terms of my social contacts.

The approach taken in this book is not this kind of imposition of a definition of the domain and its methodology; it is rather an attempt to look across the disciplines which comprise CS, intuit convergences and suggest a vocabulary. The viewpoint here is that "knowledge" (extended, as we shall see in chapter 2, beyond its definition as true justified belief) provides a good currency for trade between disciplines and when expressed in informational terms an even better one. Campbell (1982) treats the latter concept of information in terms of redundancy in a message in an appealing way.

Philosophers of mind undoubtedly bring a useful set of skills to CS; they risk irrelevance and incorrectness by over-estimating their role as they "quine" (i.e. propose as non-existent) representation, consciousness, the knowledge level or whatever. A fair general rule for the quality of their work is this; if they criticize a research program, they should propose to substitute one as rich as it in its place. It is too early to say whether the eliminativists, or Searle, or Fodor are in fact correct; using the Cartesian deconstruction above affords one hint, the rubbishing of whole fields another, and the resulting framework a third. Searle and Fodor, brilliant critics though they are, are suspect under the latter two criteria.

The path to be taken in this section is as follows:

- First, we're going to discuss the *res extensa/res cogitans* problem.
- Second, we need to get a firmer grasp on what precisely we mean by "mind."
- Third, a framework, due mainly to Merleau-Ponty, which informs the treatment in this book of some issues in the foundations of Cognitive Science is outlined.
- Fourth, these issues are re-introduced, in all their terminological glory, in the context of this framework. En route, we discuss the issue of what acceptable data for Cognitive Science are, and, as a diversion, amuse ourselves with the canards usually treated as AI's contribution to philosophy (or vice versa).

We need to do some soul-searching, as indicated above, at this point. Is such a super-discipline as CS necessary? Could we not just work from a priori considerations like the philosophers of yore? We use Jerry Fodor's work to again answer with a definite "yes" and "no" respectively.

1.4.1 Materialism or Dualism?

In a way, this section is a planned wild goose chase. In our discussion of Aquinas, it was pointed out that this statement of the mind/matter relationship is probably far too simple. However, like many other dichotomous expressions of philosophical issues, it can lead us to a wealth of insights. Moreover, this issue seems to be totally unresolvable, as framed in this way, and there is correspondingly no limit to the amount of debate which can go on.

The debate can often be very emotive in character. We find post-Enlightenment materialists, who insist that any notion of "soul" or "spirit" will throw us back into the mumbo-jumbo and Inquisitions of the Dark Ages, ranged against dualists who, with

some justification, argue that there is no way that we can maintain notions of intrinsic human dignity in a world of brute material fact. It has often been argued that Descartes introduced his notion of the Soul only under pressure from the Catholic Church. His successor la Mettrie found the courage, according to this account, to adopt Descartes' framework in a purely material sense. This argument gathers strength from the fact that Descartes destroyed copies of a potentially heretical physics tract he had written, on hearing of Galileo's difficulties. In fact, the normally sedentary Frenchman ran to the printer's to do so. Yet the theoretical framework surrounding the existence and functioning of the Cartesian soul is substantial enough to allow that Descartes was sincere in professing it.

Let's go to the matter in hand. Essentially, we're going to find Dualism a difficult argument to sustain because we can't work out how *res cogitans* could have any effect on *res extensa*. We're going to find thoroughgoing materialism almost as difficult because of its lack of explanatory power for mental life (what IS consciousness, materially?) and the inadequacy of its notion of "matter." In despair (!) we're going to examine the evidence from neuroscience and finish none the wiser. Having gone through this mill, we're going to stand back and guess which is the most appropriate viewpoint and end up in the mundane world of Heidegger and Merleau-Ponty.

Simply stated, Descartes' arguments (in his *Meditations*, which are in fact mental exercises) boils down to personal conviction that his experience of his mental life is of an utterly different nature to his experience of his body. He can, hypothetically at least, shut his eyes and deny he has a body: he can introspect, and discover in his inner (phenomenal) world some utterly certain experiences of a self, inalienably different to any physical experiences. This rock of selfhood, which both he and Berkeley were privileged to find, is the basis for the positing of the dualists' "Soul."

Try it out! You know who you are right now as you read a set of arguments against which you can readily define yourself in a book you've bought, stolen or are just browsing through. Now forget about this book with its distinct narrator's voice and off-beat illustrations and focus on finding this Self, devoid of the definition those contents give it.

Well, at a guess, you don't share Descartes' nor Berkeley's divine nature. In fact, as you search for self as an object in your phenomenal world, you find yourself trapped in an infinite regress. The more you look, the less there is to look for. Moreover, as you separate self from its contents (e.g. your attitude to this irritating Irish know-all), self seems to converge to the null set.

In fact, strangely enough, self seems a much more secure entity when in action, when defining yourself with respect to the world, than in introspection. So Descartes' *cogito, ergo sum* needs to be nuanced and supplemented quite a lot: "*Ago* (I act) *ergo sum*" is also true (see chapter 8 for why).

None of which really undermines the central Cartesian insight: Consciousness is a mystery, particularly if we are thoroughgoing materialists. There have been a host of inadequate computational and cognitive "explanations" of Consciousness in recent years, which I have exposed in (Ó Nualláin et al, 1997) and which are commented on in chapter 8. However, Descartes' conclusion that some kind of spirit hovers around

the brain, intervening when necessary, is unjustifiable. As Spirit, it cannot affect matter. Moreover, his conclusion that we can introspect and find this Soul in our experience of Self is also incorrect. We discuss these matters at length in chapter 8.

Remember, our main argument against Descartes is the problem of A causing effects on B, if A and B are utterly alien to each other. This holds whether we regard mind as being of an utterly different type to matter (substance dualism) or containing an extra factor X (property dualism). You can gather your friends around over a few beers and/or tokes to consider the tension between this undoubted incompatibility and the equally indubitable mysterious nature of consciousness. As the night proceeds, a sensible soul might ask whether there is any relevant scientific evidence. Surely we can dam this torrent of words by performing an appropriate scientific experiment? If, using the brain imaging techniques we outline in chapter 4, we track an intent from its neural activation infancy to its expression in overt action, we can then categorically insist that a physically describable circumscribed set of events has been noticed and that materialism has been established?

Well, no actually. Where did the intent content come from? Moreover, overt action is preceded by an "action potential" in the neurons which are to initiate the act (see chapter 4). Yet, even then, the issue is confused. This action potential does not inevitably lead to an action in all cases. Conscious intention can override the mechanism, even at this late stage. (I have discussed these findings in Ó Nualláin et al, 1997) and in chapter 8. The original reference is Libet, 1979). In fact, the evidence from brain imaging of this kind is incredibly ambiguous, and one can remain in whatever camp one chooses after its analysis. It is rather like a discussion on which is the best football team, where loyalty is really the only arbiter. However, we can see the issue of the freedom of the will emerging, and we discuss this in chapter 8.

Anyway, your former tennis partner says, pouring another orange juice, this is all a non-issue. All this neural action potential is very clever, but we have fundamental issues of the conservation of energy to think about. Let's say we are, like the great neuroscientist John Eccles, Catholics and dualists. How can we, as self-respecting Nobel prize-winning scientists, countenance an interaction which seems to violate the first law of Thermodynamics?

Quite simply, actually. First of all, in physics Heisenberg's uncertainty principle insists that what we observe is not nature herself, but nature exposed to our method of questioning. In fact, the so-called "objective" properties of particles in a quantum physics experiment are as much artifacts of the act of observation as intrinsic to the particles themselves. The act of conscious observation seems to affect matter.

More fundamentally, Henri Margenau's work has established the existence of "probability fields" which consume neither mass nor energy. The speculation which Eccles favors is a soul permeating a probability field hovering around the brain waiting for action potentials in order to bypass the mind/matter distinction by initiating overt action in the world. It is an inviting picture, currently irrefutable, and Eccles and his soul will enjoy external bliss in heaven for it.

However, all that I wish to point out from Margenau, Heisenberg and Eccles is that the mind/matter issue is infinitely more complicated than many standard texts make

out (Churchland, 1988; Flanagan, 1991; Dennett, 1992; Jackendoff, 1987). The question phrased in philosophical terms is what it means for an event to have both physical and mental properties. As such, it is yet to receive an answer. The picture of matter which emerges from quantum physics resembles shadow rather than stone. Neither have the many neurophysiological experiments of varying degrees of ethics ranging from the appalling to the correct yielded any conclusions. We are gong to have to look elsewhere.

I wish now to outline the viewpoint taken in this book. With Merleau-Ponty and Heidegger, we encounter an approach in which the mind/body problem is subsumed into a general view of how cognition in general functions vis à vis the world. Cognition is in the world, an expression of the more fundamental Being-in-the-world. We are mind/body unities, present in the here-and-now. I argue in chapter 8 that the Cartesian "Cogito" does exist, but as an occasional remote and non-dualist achievement. If a philosopher wishes to justify this position with respect to the area of philosophy dealing with such issues (metaphysics), we can point him to Aquinas's triptych of substance, act and potency.

And so to other issues. First, what is mind and how can we study it?

1.4.2 In Search of Mind (II)

The first issue here is: what are permissible data? We have noted the inadequacies of Ryle's approach which attempted to include only verbal and overt behaviour. With the advent of AI, the range of permissible data extended to include mental processes which could be formally described as a set of explicit procedures (algorithms), e.g. add a list of numbers by adding the first to the second, add the result to the third, etc. Let us call the total of all identifiable algorithms and heuristics "the Computational Mind." These algorithms may be doing extremely complex tasks for us, unconscious to ourselves. For example, as you read, Process A is focusing your eyes on this page and (to simplify) Process B is analyzing the sentences and extracting their meaning.

Consequently, we could decide that our search for mind should limit itself as above. Alternatively, we might decide that only processes which we could potentially become conscious of should form our data, i.e. that the phenomenological Mind is all we're concerned with. By this token, Process A, which is potentially observable (try it) is a valid datum while Process B isn't. We lose Process B by this move but we also gain a lot: we can appeal to aspects of our experience that seem non-algorithmic e.g. our emotions on hearing music or the fluctuations in our consciousness.

Yet there is more to the study of Mind than even the union of the sets defined by the data thrown up by the computational and phenomenological approaches. We shall see in chapter 5 that a great deal of agonizing is currently being done in AI as to where to place Knowledge-level descriptions. If we have a robotic system functioning in an environment, is it correct to project the "knowledge-level description" (i.e. the attribution of mind) solely to within the robot itself, or to the combination of robot and environment? The current received wisdom is that this description is the preserve solely of an observer, and cannot be attributed to the robot alone, but the observer's perception of robot plus environment. Moreover, we shall find in chapter 2 that there

exists in Cognitive Psychology a canonical principle called the Principle of Rationality. This states, in essence, that the Cognitive System will try and maximize the organism's adaptation to its environment. Where is mind now?

The answer I give is that Mind is best considered as manifest in the principles underlying the interaction and increasing co-adaptation of organism and environment over time. A child learning to function increasingly efficiently in the world shows one instance of Mind. A species adapting itself to a habitat over millions of years demonstrates another. In other words, Mind need not be, as commonly thought, the preserve of conscious thinking beings. Mind is externally present (immanent) in nature. One manifestation of Mind is Intelligence, and it is that which we as cognitive scientists are most concerned with. If we find ourselves focusing a great deal on conscious intelligence, it is because it, initially at least, promises to yield its secrets a little more readily, and seems an extremely effective form of Intelligence and manifestation of Mind. Yet we hold on to a definition of Mind which can encompass the dance of the honeybee simultaneously with Einstein's discovery of General Relativity.

The focus of this book is ultimately Conscious intelligence. We are interested also in how conscious intelligence is often parasitic on the activity of unconscious processors, how the phenomenal mind rests on the shoulders of computational mind.

We accept a weak form of the information-processing hypothesis i.e. that it there exists an information-processing level of analysis of mind intermediate between neurophysiology and consciousness. This, as we shall see in chapter 5, is considered the central premise of cognitive science. In its strong form (as expanded on in, e.g. Stillings et al, 1988) an attempt is made fully to characterize mind in this information-processing way. It is assumed that the system of informational structures can be decomposed, and the elements which form the result of this decomposition can be characterized intentionally. This characterization is often seen as a way of cashing out consciousness. The view on consciousness taken here is different; it requires embodiment and is a much more encompassing phenomenon than intentionality. Moreover, the information-processing level of analysis is not seen as in any sense privileged; it is interesting and useful, but no further commitment is made to it.

In the previous section, I outlined how the monism/dualism issue is viewed in this book. Let us now view how it stands on some other philosophical debating points.

1.4.3 Autism, egocentrism and intersubjectivity

In this section, I wish to outline one aspect of the general theory of cognition that informs this book. Intelligence and Mind can be discerned in the interaction of the body-subject with its environment. Mind is to be considered in its immanent, computational and phenomenal aspects. We hope eventually to shed light on the peculiar nature of Conscious Intelligence and such issues as selfhood and will. For the moment, however, we're concerned with a classification of the types of cognition which exist.

Cognition is conceived as comprising three modes: the egocentric, intersubjective and autistic. Egocentric cognition is essentially cognition in which the view of oneself (especially one's body) is solely as subject (see our discussion of Merleau-Ponty above).

Perception of the world as one moves is a perfect example of egocentric cognition. We noted above that AI robotic systems, which attempt to function moving around a domain by continual updating of a representation of that domain actually can manage to do this? Essentially, by combining the visual and somato-motor (i.e. feelings of movement) data in a way which extracts information from both. The posterior parietal cortex has been suggested as the most likely area for this combination (see chapter 4). Yet there need not be any explicit data about oneself as another object in the environment here: thus, we call this "egocentric" knowledge. Let's note two areas in which this type of knowledge has been studied: the ecological optics of J J Gibson (chapter 2) and Rodney Brook's Mobotics (chapter 5). Finally, Merleau-Ponty comments that one's knowledge of a new areas, as expressed through one's language, is always initially egocentric.

He noted also that our primary experience is of Being in the World with others, as a person among persons sharing a consensual (intersubjective) reality. Most recent work on child development shows an extremely early socialization (de Schonen et al, 1992). This consensual reality may be developed in some people in different ways than others. For example, a musician may be able to discern that a guitar is out of tune while a non-musician cannot; yet, what the musician hears is objective and potentially (among musicians) consensual.

Let's put that musician to work singing a song, which he has difficulty recollecting, in a warm auditorium. His guitar slips out of tune while he sings and he doesn't notice it, such is his concentration in the words. The musician is now in autistic mode, with respect to tuning. Those of his audience who never noticed the difference in any case are in egocentric mode: the weeping musicians in pain at the back are in intersubjective mode. We discuss in chapter 8 how we can move from egocentric to intersubjective mode: for the moment, let's note that autistic mode signals the lack of conscious perception of a consensual object for one attuned to such an object.

In the accompanying diagram (1.6) of a soccer match on TV, the crucial relationships are as follows: the player in possession of the ball is using egocentric knowledge to remain in possession, to keep his balance, etc. He is also, in intersubjective fashion, trying to beat the goalkeeper. Myles has had too many beers, and has watched too much soccer. All he sees are projections, without any authentic experiencing of what's really going on in the match! He is in autistic mode.

Which in turn leads us to ask: what is an object, anyway? For the tone-deaf, what is a tune? The answer to be developed here is that an object in any (potentially) consensual experience which doesn't admit immediately of scientific disproving. The Flat Earth society consensually validate an object which can easily be shown not to exist. Musicians detect a difference in quality between REM and Beethoven's late quartets which can probably eventually be verified in terms of information theory (see chapter 7).

The above, then, is one aspect of the framework for the treatment of different types of cognition in this book. Let us see how it casts light on current controversies in cognitive science, and how they reflect this light. We'll call this aspect of our framework "The Mylesian Position"; the Nolanian position will unfold as the framework gets fleshed out in the course of this book.

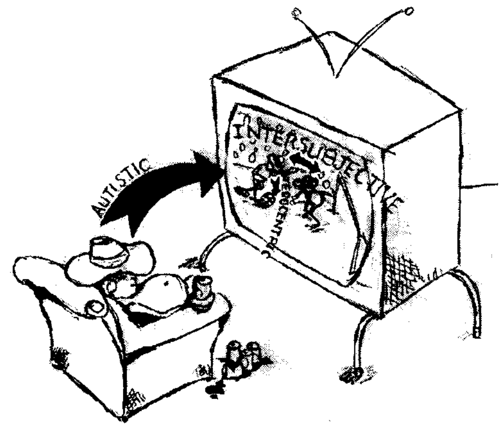


Figure 1.6

1.4.4 Some current controversies in Cognitive Science

In this section, we boat out into the stormy sea of Cognitive Science controversy. A strong stomach and nerves of steel are both basic prerequisites for this voyage, full of hurricane and pirate as it will be. The launching-party will have as theme the notion of "Understanding" and whether we can attribute this to computers. This topic will lead us to discuss the wider issue of to what extent we can attribute mental states to computers in the first place. Then, in turn, we'll find ourselves discussing what it means for two mental processes run on different hardware to be equivalent. We discuss, in particular, whether we shouldn't just try and reduce the mental processes in question to their constituent parts. We then turn our minds to the issue of how and whether we really know what we mean by what we say and think, including about these issues.

1.4.4.1 The Chinese Room

First of all, the launching-party. We'll talk about whether a computer, programmed with the appropriate knowledge structures can be said to understand a text which it processes correctly. This processing could involve paraphrasing the text, or translating it into another language (see chapter 5's discussion of scripts). John Searle's (1980) classic paper on this subject, one of the most re-printed scientific papers of recent decades, says that we must withhold predicating understanding of such a system. We discuss just the bare bones of his "Chinese Room" argument here. It is impossible to do any reading in the AI area without continually coming across his article.

Consider the situation depicted in this diagram (1.7). A man sits inside a room, committed to a life of translating English to Chinese without knowing any Chinese (is this Searle or Beckett?) However, he does have a set of rules for the equivalences of Chinese and English words. Shown a Chinese squiggle, he can match it with his tables of equivalents, and produce an English equivalent. The text in Chinese may be regarded as input, the text in English as output, to extend the computing metaphor. He might even have another set of rules by which he can, equally automatically, recombine the constituents of the English sentence in their correct order. Searle

introduces many variations of this basic theme, in the manner of a picador at Pamplona: he is trying to goad his opponents in the hard AI (yes, computers *can* understand) camp.

Yet his argument boils down to a very simple issue. Since we'd be loath to suggest that the person in the room actually understands Chinese, and we must accept that he's working like a computer production system (see chapter 5) in conjunction with his rules, are we not forced to conclude that computers cannot understand? We have seen that his target is the hard AI school: yet the soft and medium schools, while different in emphasis (for example, Sloman, 1992), also are part of Searle's prey. Replies to Searle from the Hard AI school have focused on asking whether the system of man plus rules together may be said to understand, and processor plus program be similarly assumed to understand. The level of vitriol in the debate has been staggering. For example, I was shocked to see the epithet "religious" being hurled at Searle by Douglas Hofstadter.

It is fair to say that Searle's instinct for the jugular is faultless. However, his position changed greatly over the years. His earlier paper (1980) was willing to grant that understanding was a property of programs unique to the human brain. After some deft footwork, he found himself stating that this type of position is in fact dualist. We're basically positing a contrast between a *res cogitans* (the program) and a *res extensa* (whatever the program is being run on, e.g. a Turing Machine – see chapter 5). We're attributing understanding, mental states and so forth, only to the program. His latest incarnation (1992) won't grant the syntactic operation inherent in programs any intrinsic physical reality; echoing Kripke on Wittgenstein, he declares that syntax is not intrinsic to the physics. (The views of this avatar on the CS enterprise in general we discuss in chapter 5.)

In my framework, understanding can be viewed correctly only in the context of a "situated" act of cognition. It is part of a life-process. Let's note, parenthetically that understanding covers a multitude. Had Vernon Howell's mother managed to stop the siege at Waco before the carnage, we would have accepted that she understood David/Vernon. This extreme is empathy. The other extreme is understanding how $x^2 + y^2$ gives the square of the hypotenuse, where x and y are the other two sides in a right-angled triangle. We see later that fully conscious acts have a privileged status in this framework.

Understanding is either such an act, or the recapitulation of such an act. Were an autonomous system like a Brooks "Creature" to perform symbolic behaviour like that in the Chinese Room, we might concede that it understands. I have argued elsewhere (Ó Nualláin, 1992) that this cannot happen, given the current design-principles of such systems.

Finally, Searle comments sardonically on the "courage" of such AI scientists as John McCarthy who continue to predicate understanding of computers, beliefs of thermostats, etc. Indeed, we can't stop them doing so. The moon can be a ghostly galleon, banshees can wail, poets can anthropomorphize the "cruel" sea and "kindly" sun. However, what is really important is that the problem of predicating

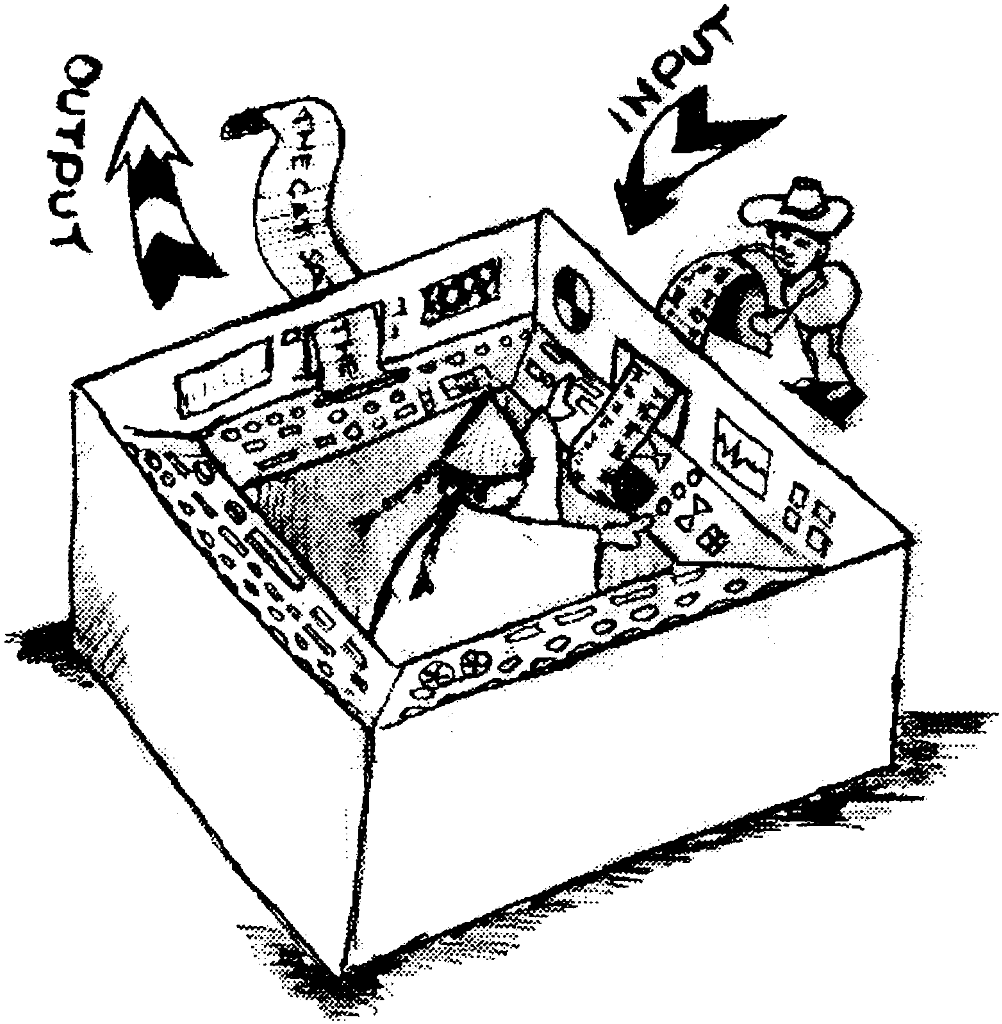


Figure 1.7

understanding should be seen in a larger context as part of an overall theory of cognition, and that is one of the goals of this book.

1.4.4.2 Equivalences

In this subsection, we discuss when we are allowed to attribute equivalence of process between two cognitive entities. Example A: if we have a person calculating a payroll and a computer doing the same, with precisely the same eventual output, are we entitled to assume that they have followed the same steps? Example B: if we have a neural network (chapter 4) performing a memory task (e.g. remembering the months of

the year in Swahili) and an American doing the same task, what criteria can we use to conclude a similarity in the nature of processing? Example C: If we compare the rule application sequence of an expert system (chapter 5) and the stated sequence of logical operations by a human mathematician working on the same task, what are the grounds on which we are allowed to assume equivalence?

Well, I wish to spoil the fun immediately. What we're talking about in examples A, B, and C is computational equivalence. (Let's note that in the computationalist cognitive science paradigm we explore in chapter 5, the most relevant equivalence is at the level of "functional architecture.") The criteria we use in all these examples are:

1. Input-output behaviour (obviously, this must be extremely similar). We also expect that changing the task (e.g. increasing the number of months!) will cause equivalent output changes in the two systems (e.g. amount of error).
2. Speed of processing. It is thus doubtful that example A shows any sort of meaningful equivalence.
3. Where a meaningful comparison can be made with respect to intermediate processing, e.g. in C, we can infer that the mathematician's "protocol" is informative enough to assume equivalence.
4. We may decide, with Pylyshyn (1984), that true equivalence can be posited when one has established equivalence of "functional architecture." Essentially, this involves establishing identity at the level of computer architecture. This position is arrived at after much careful consideration of the foundations of CS, and we mention it in this context in chapter 5. We can reject it on the grounds that there are no good reasons for accepting the remainder of Pylyshyn's framework, unless it is considerably modified.

This, in turn, leads us to the question of what our methods of investigation should be in Cognitive Science, and the related question (again) of what are relevant data. The answer is that we're studying all aspects of Mind, and consider everything from computational performance to input-output relations to protocol analysis valid.

Fine. But computational equivalence does not equal experiential phenomenological equivalence. According to the functionalist thesis, we are allowed to infer (almost) every type of equivalence from the functional one. I deny this, and am about to be accused of being religious, I think. What I wish to point out is that we do have privileged first person (e.g. you and me) access to our experiences in a way which cannot be reduced to functional equivalence. In other words, consciousness is an issue here. I can bear the hounds baying as it looks as if I've put all aspects of personal experience outside the range of scientific inquiry. Quite the opposite: what I'm saying is that these problems of inaccessible data only arise in a Cartesian framework. When we accept that much of our experience is primarily intersubjective, and as such consensually valid (in the sense outlined in chapter 8), there is no such problem about observables in a scientific sense i.e. in informational terms. That aspect of our experience which cannot be put in those terms is admittedly currently outside CS.

1.4.4.3 Reductionism

There are various types of reductionism possible, ranging (rather like curry powder) from the mild to the very hot. In Cognitive Science, given the failure of Ryle's project, reductionism concerns itself now mainly with attempting to reduce experience to neural activity. However, we know remarkably little (see chapter 4) about how neural activity results in the fully human symbolic/emotional vast palette of experience which we all enjoy. Consequently, reductionism can be usefully classified also with respect to the degree of hope involved about breakthroughs in Neuroscience over the forthcoming decades.

The most hopeful reductionism is called eliminative materialism. The adherents to this faith live in hope for such radical breakthroughs in Neuroscience that the "folk psychology" concepts of "belief," "desire," "knowledge" and – God forbid – "hope" itself can be abandoned (Churchland, 1988). This book is hopefully being read in a liberal democracy, and we allow people believe what they like in such political systems. However, it is not scientifically valid to construct a science of cognition on such a poverty of neuroscientific findings, let alone prescribe what are valid constructs for viewing one's experiences on this meager basis. In fact, I believe it valid to allow a construct like "intent" in Cognitive Science. Again, the telling argument is that it is quite definitely an integral part of the intersubjective realm. In fact, massive court cases can hinge on what the defendant intended at time X, and a great deal of evidence can be adduced to buttress whatever the theory is.

Were it possible to reduce experience to neural event, we would be scientifically obliged to do so. However, the integrity of neuroscience, as a discipline, right from the time Lashley failed to find his engram (see chapter 4) has been demonstrated in its ability to take on board findings which make its set task much more difficult. We are left picking through our experience to try and find clues to solve the main problems of conscious experience. In a sense, then, Merleau-Ponty's work in *The Phenomenology of Perception* is actually reductionist: its reducing our experience of the world to its barest essentials, given the fact that we don't know enough Neuroscience to get closer to the bone.

We should not be surprised, contrariwise, if the failure of our attempts to reduce conscious experience compel us eventually to transcend our experience. We should have the integrity to accept that through Cognitive Science our worldview may be changed in the direction of enlargement as much as reduction.

1.4.4.4 Meaning

In this final subsection, we're dealing with several apparently unrelated issues. The first is again the question of privileged access to experience i.e. the extent to which you can claim that a given experience is yours, and yours alone. The next is what is known as the semantical problem: how do our names for these "private" mental states get their meaning? Related to this is the problem of how we can say that humans have mental states at all. We find ourselves asking how we can mean anything. Is there some kind of monitoring process in the brain which sees the symbol "dog" and means this quadruped with fur, claws, etc?

I wish to argue that these issues are intractable only within a Cartesian framework. If we want to posit as the only mechanism this monitoring process, this unmeant meaner (see Dennett, 1991), we end up with Descartes' schema. Once there, we're stuck very badly. So you've got this unmeant meaner within you which means things! How is it you can talk to me? Is mine of the same structure? Quickly, we're forced to concede, as the paradoxes multiply, that maybe we don't even have privileged first person access in the way we thought (i.e. as sole owners) to some of our experience. Mundanity insists that meanings are built up gradually from the subject's (dialectical) relationship with his environment. There is no absolute separation of the within from without: the meanings define the relationship between subject and object (see chapter 2 in Piaget). Moreover, just as there are different kinds of objectivity are possible ranging from egocentric perception to intersubjective elaborate symbolic behaviour, so also do the types of meanings vary.

Where then does the self come in, if there is no unmeant meaner? Essentially, in the preservation of relationships between subject and environment. The function of self as a cognitive system is the preservation of achieved relationships between the subject and its environment (we explore this idea at length in chapter 8). Therefore, I agree that we don't have privileged access to our mental states/meanings in the legal way, for example, a householder can ask unwelcome guests to leave his property. If these mental states are valid (intentional) as distinct from neurotic, they are necessarily part of the intersubjective domain as expanded on in chapter 8. The meanings they carry are therefore potentially shareable. How then do they get their names? In the same way as "dog" and "house": it's a matter for etymology, not the philosophy of mind. How do we know others have mental states? A better question: how can we possibly doubt it, given that the starting-point for conscious experience and knowledge in the first place is the intersubjective world?

In the framework here, therefore, meanings are artifacts of the dialectic between subject and world. So-called private mental states can often be properly studied as part of intersubjective analysis. Self's cognitive role is preserving subject/object delimitations. There is no Cartesian homunculus, or Unmeant Meaner. We are present in the here and now with others. Understanding in this framework (1.4.4.1) is viewed as arising from the organism's attempt to achieve meaning. The debate on this issue in AI could not be more wide of the mark: understanding is always the result of conscious effort, results in a sense of meaning where previously there was confusion or chaos, and as the result of an act of will is beyond the reach of any non-biological system. The psychiatrist and concentration camp survivor Victor Frankl has written best on this role for understanding.

Conveying meaning to another person, as will be repeated, is a conscious and often willed action. Under the auspices of symbols I know to be intersubjective, I attempt to convey a certain point of view to you. Yet "I" am partly defined by this attempt (to answer T S Eliot's plaint that it is impossible to say what I mean, I am just what I mean) and cannot be other than conscious as it proceeds. Meaning in this sense is therefore tied in with intent and we should not find it any easier to formalize than the latter; any major criminal trial which attempts to intuit the precise "intent" of a suspect

shows how difficult this can be. If we can establish a separate domain within the intersubjective realm for value, we may find our theory of Cognition mounting to an ethics. However, that would be the theme of a much larger and more important book than this one.

1.4.5 Fodor and Modularity

In fact, according to Jerry Fodor, this book probably shouldn't have been written: one of his more celebrated edicts is on the non-existence of CS. It is difficult to know whether Fodor fits best in this chapter or the next. His modularity of mind thesis (Fodor, 1983) is a set of prescriptions which cuts across both disciplines. As a compromise, he's in both. There is very little to argue with in Fodor's general approach to the mental per se: he argues, contra behaviourists, that mental events are causal, and that a paramount aspect of the mental is that it is intentional. He insists, in a more controversial vein, on the existence and crucial causal role of an innate "language of thought," the development of which is genetically predetermined and comprises all of cognitive development (see 2.4.2.5).

It is with the modularity thesis that we are more concerned here. Fodor makes a distinction in the large between modules (roughly speaking, fast, unconscious processes structurally similar to process B in 1.4.2) which are "vertical faculties" and a "central system," handling such global, non-automatic processes as problem-solving. There is much more of experimental import in the former than the latter. In fact, Fodor's law of the non-existence of CS is predicated on the inaccessibility of central systems to the methods of investigation of CS. The most important characteristics of vertical faculties are the following:

1. They are domain-specific. We can demonstrate, for example, that there is a distinct capacity for phonology (see chapter 3) which is unrelated to any other aspect of language.
2. They are genetically determined. Taking phonology again, we find a universal pace and sequencing in phonological development, independent of the particular range of stimuli which the child is experiencing.
3. They are associated with distinct neural structures. A lesion in the posterior perisylvian sector disrupts assembly of phonemes into words (Damasio and Damasio, 1992), leading to the obvious conclusion that this neural structure is related to that task. Near the sylvian fissure is the structure responsible for the grouping of words into sentences, i.e. syntax (ibid). The viewpoint of this book, contra Lakoff and Edelman (see chapter 3) is that these points about the autonomy of aspects of the language faculty, or perhaps a general symbolic faculty, are well-taken. (See my contributions in McKevitt et al, 2000).

Fodor's terminology has proven a little confusing, in that he speaks a great deal about "input systems," leading some researchers to believe that he is talking solely about perceptual processes. Let us keep in mind that this is not the case as we continue:

4. The operation of input systems is mandatory: once we know a language, we can't possibly hear it as noise again.

5. Input systems are fast, as anyone specializing in computer speech recognition can tell. Sampling must be done at about 40 KHz.
6. They are informationally encapsulated, i.e. they don't "know"anything about the higher cognitive functions being executed.
7. Only the output of an input system is available to consciousness.

And so on, and so on. It behooves us to point out a few points:

First of all, as Jackendoff (1987, pp. 247–272) has pointed out, the original modularity thesis doesn't allow for the existence of reading, because the visual module is communicating directly with language-specific lexical (word) information.

Secondly, there must be more than one type of central system in order to cater for the different types of intelligence that exist: interpersonal, bodily-kinesthetic (i.e. sport and dance), etc. However, these are not the main issues I wish to confront, important though they are.

The principal issue is that Fodor makes claims which cover a variety of disciplines: developmental psychology (claim 2); neuroscience (claim 3). In short, he needs support from the variety of disciplines which comprise CS. Secondly, even the glimpse we've just had at the range of non-vertical modules which might exist indicates that his caveats about studying them are not well-placed. In fact, it makes his work prone to trivialization; we could spend all our research time finding psychological processes conforming to his criteria for "vertical," call the rest horizontal and thus beyond our ken, and leave it at that. We can regard Fodor's system as an interesting hypothesis about the nature of Cognition which may or may not prove of heuristic value. It is a good example of the activity of philosophy of mind, as outlined above.

Fodor's latest set of views are provocative as ever. We already saw an outline; let's see the details. He refuses to admit of the existence of a knowledge level in cognition. In conjunction with this is an insistence that all views of semantics dependent to any extent on the existence of such a level are just plain wrong. The knowledge is encoded on the lexicon and the development of cognition is manifest a fortiori in that of the lexicon. The only view of objectivity he will countenance is semantic functionalism; in the manner suggested by Skinner, reference is achieved only by lawful covariance between external event and sign. Asked for an example, Fodor is stumped. Sitting rather uneasily with this view is an unrecanted innatism; the words which are the concepts are learned by the unfolding of an innate germ of language. And, yes, Fodor will seriously argue that such concepts as "quarks" and "black holes" are pointers to innate such concepts. It is ultimately a mystical view; the child, from birth, is a microcosm of the universe.

Fodor takes time out to excoriate Ray Jackendoff and other sentimentalists of knowledge. (Were anthropologists like Hutchins not guilty of infinite regress, the issue would not arise; knowledge, à la Piaget in chapter 2, is a fortiori internalization. However, this operation in turn requires a mind which can somehow divine precisely the salient features of the environment without previously being in contact with it). Jackendoff insists that a word like "keep" will change meaning with change in the semantic field in which it's used. The key to their disagreement for Fodor is that

semantic fields can't exist; for Jackendoff, it is the protean nature of words like "keep." It weighs in the latter's favor that he does not return as empty-handed as his opponent with respect to examples.

1.5 Mind in Philosophy: summary

We're now going to review the notions of mind which have surfaced in this chapter. We do so again in chapter 9. As we review them, we'll again find that to propose a notion of mind is necessarily to posit a set of relationships between mind and world, subject and object. We conclude by restating the theoretical framework of this book with respect to these issues.

The first coherent notion of mind we encountered was the Pythagorean notion that formal systems like number were the truest reality. The link between mentally representing a number and the external reality pointed to was assumed to be direct. Reality was coherent and best described in terms of natural numbers, which are easily mentally represented. The Pythagorean heretic who proved that the square root of 2 could not be expressed as A/B where a and b are natural numbers, apparently met with a boating accident.

Platonism is even more extreme in its Idealism. Even white objects were assumed to derive their color by reflection and/or participation in some celestial Form of whiteness. The human mind functions in this system by coming into touch, gradually more directly as one's character improves, with one of these Forms (we shall have a little to say on this in chapter 8). Both the Pythagorean and Platonic schools were schools of ethics as much as epistemology, and indeed regarded the two disciplines as inseparable. Surprisingly, we've seen that several modern mathematicians (Gödel and Penrose being the best examples) are avowed Platonists. How else to explain our intuitions about infinite sets, other than by proposing their Platonic existence? They certainly don't exist on earth. With the Platonic school, we find ourselves discussing the notion of Nous, or mind as an ordering principle in Nature. In modern terms, we can discuss this in organismic terms with respect to progressive adaptation to an environment, or in physical terms as stabilization of energy configurations, given the first and second laws of Thermodynamics, the reality of "dissipative structures," etc.

Alternatively, we can focus on mind in the act of understanding. The Aristotelian/Thomist tradition tends to objectify knowledge, assuming a rigid contrast between a subject who knows expressed in a rigidly formalized entity called Knowledge (the nearest analogue we have here to "mind") and objects which are known. It is not denied in this book that such a dichotomization between subject and object can exist. What is proposed, however, is that it is an occasional achievement of the person, attained with some difficulty, rather than a continual state. We progressed to Descartes, the modern formulation of whose philosophy is due to Eccles. According to the Cartesian framework, a totally self-conscious mind floats around the head, waiting to intervene by processing the neural signals which are completely automatically delivered to it. Obviously, this fits neither with our introspective experience, since our inner gaze fails to uncover this rock of selfhood, nor with the fact that a great deal of information processing is actually done peripherally (i.e. by the

sense organs themselves: see the discussion on J J Gibson in chapter 2). In fact, the absurdities that ensue when perceptual processing is treated as being informationally of the same type as higher-order mental operations (e.g. deduction) are so striking that Berkeley managed to squeeze God into the computational processes involved.

When you subtract God from the Berkeleyan schema, you end up with Hume's notion of mind as a sequence of now loosely, now tightly connected states. Knowledge consists of sense-data with a priori structures facilitating the development of laws of mathematics, logic etc. With Kant, however, we become aware that our explanation of formal systems like these must become a great deal more sophisticated. There is a tension in Hume's account between the barren wilderness which comprises mind and the neat structure of a priori knowledge allowing, inter alia, causality and logic. Our concept of mind must allow for purely internal processes which structure the incoming sense-data in an informationally rich way (categories). The focus of our study of mind becomes the delivery of the structure of these categories through whatever means (psychological and/or computational) are available. The framework of this book acknowledges that in Kant philosophical epistemology reached a summit of some kind. What would remain to be done in Cognitive Science in a purely Kantian interpretative context is the following:

1. To unearth the processes of development of these categories and their formal structure at all stages of their development (chapter 2).
2. To look at how knowledge is expressed by language, and indeed how on occasion it cannot be (chapter 3).
3. To develop some plausible neuroscientific descriptions of mind (chapter 4).
4. To review how the formal description of mind can and cannot be implemented computationally (chapter 5).
5. To review mind in different species and across different cultures (chapter 6).
6. To study mind in action. We need to look in particular at how symbol-systems work. As they function, we see a coalescence of a formal system, some non-symbolic "operational knowledge," other "ontological" knowledge relating to one's role in the world, a model of the task and finally attunement to the emotional aspects of the situation. We find this coalescence common to the apparently disparate worlds of language, vision, music and mathematics (chapter 7).
7. Finally, we need to discuss how all the preceding steps relate to one's conscious experience of the world and oneself (chapter 8).

1.6 The Nolanian Framework (so far)

We're adopting the Mundane viewpoint here for a few reasons. First of all, it seems impossible to explain cognition without an explicit theory of the body. Secondly, its treatment of the mind/matter controversy is not only a sensible way to view this intractable problem, but also leads one automatically to consider cognition as a subspecies of being-in-the world. That's where we actually want cognition: it's not some disincarnate process of the soul, but a necessary accompaniment to being alive. Therefore, we find ourselves encompassing knowing and being in a single sweep. Moreover, we now have a neat way of treating what cognitive development really

consists of: it's the process of coping, embodied, progressively better with a changing environment.

The Mylesian framework involves a tripartite analysis of cognition. With respect to a given task, we can be egocentric, or either autistic or intersubjective. Unquestionably, this framework demands much research: we note from Gibson in chapter 2 and Brooks in chapter 5 what egocentric processing can involve: we cannot speak about pragmatic aspects of language in chapter 3 without much reference to the reality of the intersubjective world: we note also in chapter 2 how to specify conditions about moving from the autistic to the intersubjective realm, and vice versa. Another new problem is that of attempting to characterize the egocentric domain in experiential terms, given that it is normally not experienced consciously. That was Merleau-Ponty's major achievement in *The Phenomenology of Perception*.

We are insisting, however, that the facts of experience which he makes explicit are not currently reducible in any meaningful way to mere external data, be that data neurological or behavioural. Where fault-lines exist in Merleau-Ponty's work, they tend to be in the old philosophical mistake of construing perceptual and higher-order cognition as being on a continuum, or in related fashion failing to see discontinuities between the egocentric, autistic and intersubjective domains. In general, then, we find useful the Kantian framework with the CS research program it implies as a description of explicitly symbolic, representationalist cognition: for the interrelation of body-subject to world which precedes cognition, we find Merleau-Ponty's account of great heuristic value.

Further Reading

For pre-modern philosophy, the most worthwhile text is Copleston's (1962) mammoth *A History of Philosophy*. Copleston's account of the moderns is perhaps bettered by Ayer's (1982) *Philosophy in the Twentieth Century* and Passmore's (1966) *100 years of Philosophy*. Jacob Needleman's (1982) *The Heart of Philosophy* is a passionate plea for a return to concern with the great game of Ideas in the activity of philosophy. Kenny (1973) is a lucid introduction to Wittgenstein, Steiner (1978) performs a similar task for Heidegger, and Meyer (1982) proposes a compromise between Wittgenstein's two incarnations.

2. Psychology

2.0 Why is Psychology so difficult?

What is Psychology? The answer normally given is "The Science of Mental Life." This Science has in the past included behaviourism, one of the central tenets of which is that the mental is non-existent (philosophical behaviourism) or too difficult to try and study (methodological behaviourism). What is certain is that it's not a terribly successful science, if compared to physics or chemistry. We go to counsellors with a deal of skepticism: we tend to rely on concepts from the inherited wisdom of our culture, rather than scientific psychology, when searching for insights into ourselves and others. Let's be honest, we find psychologists, particularly academic ones, in general quite a weird bunch and tend to wonder what went wrong.

There are several formal difficulties with psychology as an empirical discipline. In the first place, the subject-matter has the unpleasant habit of reading what you've just written about it and may even be perverse enough to change its behaviour the next time round. In that, psychology belongs to social sciences like economics. A supposedly objective appraisal of a company's chances of survival, printed in the appropriate newspaper, can often deliberately be the death knell or resurrection of that company. Similarly, psychology's supposed descriptions of what one's inner experience and/or behaviour should be often has the effect of self-fulfilling prophecy. We shall notice this once more in the discussion of consciousness and self in chapter 8.

What we're trying to do in psychology is somehow to objectify what it is to have subjective experience. That's another difficulty. Anything we write down should be universally valid and compelling. We should be able to precisely describe experience and predict the motions of the currents of psychic life. Several attempts to do this have been made of varying degrees of scientific credibility and power. There is no denying the power of Freud's system: in his analysis of sexuality, he managed to hit a spot at which a lot of us are sensitive and build an infra-structure which included a philosophy of civilization on this. Unlike Freudianism, on both counts, behaviourism has little power in this sense and huge scientific credibility (Hudson, 1972). The major problem, then, is mapping significant areas of experience in a scientific and compelling way. In this sense, Merleau-Ponty's work can be viewed as significant psychology, or, more precisely, what we discuss below as phenomenological psychology.

Moreover, psychology has the opposite problem to the emperor of children's fable: it wears too many clothes, but the spectators are unwilling to say so. Let's be honest: were our cognitive psychology powerful enough to describe the thought-processes of creative artists and mathematicians, to take but two examples, then it would have the potential to be a kind of super-art and super-science. Perhaps it might be on safer ground if it claimed to explicate these processes in retrospect. It should, moreover, tell us something significant about the processes of thinking through everyday problems to

solution. Were it able to do this, we would say it had "ecological validity." In other words, it should, inter alia, be able to handle the type of situated cognition situation we brought up in chapter 1. To do its task, it may have to venture outside that realm classically considered "cognitive" as we do in the treatment of affect in this chapter.

Let's review some of this argument. Psychology should tell us something certain we didn't know before studying it about our experience. That's a very difficult task, as it turns out, because that something is going to have to be universal and non-trivial. It's fair to say that no such psychology currently exists. People tend to go to religion, or to those paraphrases of ancient wisdom which are known as "esoteric psychologies" for that kind of psychology.

The companion volume attempts to find a way through this morass. In many ways, it's better to consider the analogy of philosophy, discussed in chapter 1. Because its role as worldview-creator has been pre-empted by the independent existence of the various fields, philosophy contents itself with its role as rational inquiry in any field. Similarly, psychology has seen secessions from cognitive science: the attempt at the description of mind as an informational system; and soon, perhaps, phenomenological psychology, which is inching toward the burgeoning field of consciousness studies. The accompanying volume argues for a new field called Noetic Science which follows Quine's dictat that mentation is not the mind alone. Mentation is most manifest in such expressions of mental activity as technological artefacts and scientific theories. (In this, Quine is of course compatible with such as Edwin Hutchins who emphasises the role of cognitive artefacts, inherited in one's culture, which aid the individual mind.)

In particular, Noetic science attempts to assess which aspects of scientific theories are truly objective, and which are idiosyncratic expressions of the human cognitive apparatus. The realm of psychology is shrinking. Nor are we going to take as a remote possibility the claim that psychology can be a "superart" or science as mentioned above.

Finally, we have to take into account the arguments we will note in chapter 8 about the political malleability of the self-concept; as it mutates, so will psychological theory alter. The classic example here is of course the soviet psychologists. We will discuss Vygotsky in chapter 3, but I must forewarn the reader that Vygotsky was forced to emphasise the public, social dimension of child development by his contemporary Stalinist regime. As I ask (in Ó Nualláin 2000a), what then can psychology be?

The answer is that psychology can be understood as the "Search for Order in Human Affairs" and as such is capable, theoretically, of encompassing all other disciplines, allowing for the secessions just enumerated. In these companion volumes, the role I conceive for psychology in the long term is as follows; the assertion of those almost ineffable traits and values which we recognise, now intuitively, now "rationally" (depending on the Zeitgeist) as of human value in whatever scientific and political culture psychologists finds themselves. Psychologists may in our times, for example, validate the appreciation of beautiful things as a way of life because physicists regard beauty as an objective quality of their equations. There is also a role for a separate discipline of psychotherapy, untangling the authentic from the bizarre in the cognitive-emotional complexes which lead clients to counsellors.

What we're concerned with here is cognition, and recommendations for computational description thereof, when appropriate. At the end of this chapter we should know more about what situated cognition looks like, experientially and computationally. We have much ground to cover before we get to this point:

- First, we describe the history of psychology, focusing on its incarnation as experimental epistemology since the mid-nineteenth century.
- Secondly, we review the types of methodology which have proven valid during this brief history.
- We then proceed to discuss what is known about perception, and the extent to which it can be distinguished from cognition.
- Then follows what is by far the largest section in this chapter: the one dealing with memory. We find memory to be a multi-faceted phenomenon.
- Memory is initially viewed in terms of information-processing theory. We need to know what kind of structure it has in these terms, and also what kinds of information it actually processes.
- We then discuss memory in terms of how its contents got there in the first place. What is learning? How does remembering happen? How does memory relate to the organism's life itself?
- Perhaps the surest way of solving a problem is through memory i.e. remembering a previous, similar case and applying its lessons. I always leave my office keys in the door! Is this the only way? Which kinds of problem-solving experience are remembered, and which are forgotten?
- Moreover, is there a pattern to this forgetfulness? If so, is it simply informational overload or is there a darker, upsetting type of process at work?
- Finally, are we simply the sum total of what we remember? If you'd had my experience of life in its fundamental aspects, would you be writing this book? And, mutatis mutandis, would I be reading it? We then review the theme of mind in psychology. As previously mentioned, the situated cognition approach is then detailed. Let's get on with history!

2.1 A brief history of Experimental Psychology

2.1.1 Psychophysics and Behaviour

First, let's look at the word psychology itself. It is the "logos" (study) of the psyche or soul. For Plato, as for Descartes, the soul was immortal, indestructible, and totally other to matter. For Aristotle, the soul in all organisms is their animation. In fact, it resembles a set of skills more than any disincarnate mind. For example, we say in the Aristotelian framework that humans are rational by virtue of their souls. The soul is the form of the body, in the same way as the statue's form can be distinguished from the marble which comprises it. There is thus no need in the Aristotelian framework, as we noted in chapter 1, for agonizing over mind/matter interaction. The unitary substance of the person, the psychophysical unity, can be conceptually separated into form and matter, with its form being the soul.

We've seen that a great deal of debate in epistemology used psychological evidence as a touchstone. Berkeley commented on how perceptions weave and bob. Hume

introspected and found a chasm where he expected a soul. However, it is only from the early nineteenth century onward that psychology began to be studied experimentally. Essentially, the sense-data began to be measured in some metric or other (e.g. auditory intensity in decibels, frequency of tactile stimulation in hertz) and attempts made to calibrate the felt response.

Many of the pioneers were German: Weber, Fechner, Helmholtz, Herbart, Wundt. Herbart and Helmholz produced theories of unconscious processes in perception. The attempt to quantify perception and sensation noted above was called psychophysics. Fechner produced the first mathematical formulation of the relation:

$$S = k \operatorname{Log} I + c$$

where S is the intensity of the sensation, k and c are constants and I is the objective, physical intensity of the stimulus. Several consequences emerge from this. It is the first ever relation of a measurable to inner experience, and as such is sometimes regarded as the birth-cry of experimental psychology. In fact, the date on which Fechner formulated it (22 October) is sometimes celebrated by psychologists as a birthday! Secondly, it is a logarithmic relation between the inner and outer, one of many such we will review in this chapter.

Finally, it is a type of Pythagoreanism. Interestingly, it derived from Weber's study of just noticeable differences (jnds). These were measures of the smallest differences in external intensities that could be detected. The notion of threshold, or jnd, is central to psychophysics. Let's note that none of these scientists were actually professional psychologists, since that appellation did not yet exist. The major figure from this era, Wilhelm Wundt, was a Leipzig professor of philosophy who gave scientific demonstrations in his extremely well-attended lectures. Wundt's early concern in his formulating a scientific psychology was creating laboratory conditions in which introspection could be objectively studied. (Let's note that we're right back with our original problem of objectively describing experience in a consensual and compelling way.)

Wundt had that German immunity to boredom which Anglo-Saxons, let alone an excitable Celt like myself, in general do not share. His goal, a psychic atomism, was in intent not far from Wittgenstein's logical atomism. Complex mental states were to be analyzed into primitive sensations and primitive elements of affect. (Wundtian analytic introspection (describing the sensations and feelings using the vocabulary the experimenter feeds you) differed from

Würzburgian phenomenological introspection (describing what's going through your mind in your own words). The Würzburgian technique is still in use in cognitive psychology. Nowadays we call it "thinking out loud. " I owe this point to Robert Campbell). Let's take an example. In investigating the affective aspects of rhythm, Wundt set metronomes for various patterns of rhythm (and arhythm), lay back and observed his feelings. He postulated that his reactions could be plotted as points (x, y, z) in three-dimensional space. In other words, every sequence had particular values along the pleasure, strain and excitement dimensions. Wundt later abandoned his

scientific work to focus on the residue of wisdom encoded in culture, or folk psychology.

Perhaps this change had something to do with the limitations of his initial methodology. How could he be sure that someone else hearing the same rhythm would have the same values (x, y, z) as he? A more complicated question in introspection then arose with what was called "imageless thought." While some experimental subjects (Ss) reported thought without images, others did not. It's possible that this issue can now be resolved with respect to the extent to which one functions visually or not. In the fledgling science of experimental psychology, it was a catastrophe. In fact, it gave the philosophical and methodological behaviourism of J B Watson, which we look at presently, its earliest impetus.

First, let's look at the work of another excitable Celt, William James, brother of the novelist Henry, medical doctor and philosopher. James is not really a systematizer, let alone a psychic atomist like Wundt. His major significance is that his is the first thoroughgoing, presuppositionless and scientific (i.e. naturalistic) study of conscious mental life. He regarded nothing in conscious mental life as outside his scope, and eventually indeed published a book titled *The Varieties of Religious Experience*. A close reading of his massive *The Principles of Psychology* reveals his acquaintance with much supposedly modern research on perception and its difficulties.

James characterizes consciousness as essentially simple sentience or awareness. Conscious mental life is, above all, purposive and dynamic. It is to James that we owe the definition of psychology as "the science of mental life." His account of his own experience (getting out of bed!) is often brilliant; his neuroscientific and perceptual knowledge are still surprisingly impressive; but… he did not develop principled methodologies with replicable results. This too left the door open to behaviourism, which became the dominant force in American psychology for nearly half a century.

The first and one of the most thorough behaviourists was Ivan Pavlov, whose key work focused on the salivation reflex of dogs. Salivation is normally an unconditional reflex (UCR) to an unconditional stimulus (UCS) such as the showing of meat. Let's introduce a conditional stimulus (CS) by ringing a bell before the meat is displayed. We find, to our surprise, that the CS can produce salivation (CR), even in the absence of the meat, after a training period. We now have a basis for understanding how innate inner reflexes can be adjusted to respond to processes in the world to which they were not originally attuned. In short, we have the basis for a coherent methodological behaviourism.

Nor was this the only attempt in the early nineteenth century to reduce cognitive operations to physiological process. It was noted, for example, that plants move toward the sun with what's called a tropism. It began to seem that a combination of tropism and adjustment of reflexes, as postulated by behaviourism, might explain much behaviour. It was left to J B Watson to supply the polemics for this new approach to psychology, which he did remarkably well. His career ended, alas, when he fell in love with one of his students, commenting to her in a manner which upheld his integrity as a behaviourist that all his responses to her were positive, and his major achievement in his later commercial career is said to be the idea of putting the candy

bars beside the cash registers in supermarkets. It's perhaps significant that two of the most reductionist intellects of all time, Watson and Auguste Comte, both fell in love unexpectedly in middle age with major changes in their careers as a result.

Watson's and Pavlov's "classical conditioning" is not really sufficient to explain how we invent apparently spontaneous behaviour not immediately related to reflex. My writing this book and your reading it are examples. B F Skinner provided the more powerful notion of "operant conditioning" to explain this sort of behaviour. In Skinner's system, the organism emits behaviour (operants), some of which are rewarded by the environment: ordering a beer is rewarded; putting one's hand in the bar's cash register is not. We call the differential rewarding of operants their reinforcement. We can decide to reinforce continually, at intervals, negatively (by punishment), or not at all. Moreover, we can change the motivation of the organism by reducing its body weight (i.e. starving it). The classical Skinnerian experiment had a pigeon in a steel box with a green light; the reinforceable operant was pecking at the light.

Actually this schema is quite powerful. Essentially, it boils down to the statement that for every repeated piece of overt behaviour there must be some kind of reward. Combined with classical conditioning, we get an apparently all-inclusive psychology which deals only with observables.

What of large-scale coordinated activity like performing a piece of music? The behaviourist view is that this is explicable with respect to successive attempts (approximations) at achieving it being differentially rewarded. We'll see in chapter 3 that this can't explain language acquisition and in chapter 5 that the CS notion of mind as computation over representations provided a powerful and antagonistic alternative metaphor to behaviourism. For the moment, let's note that behavioural therapy for destructive habits has its uses.

2.1.2 Phenomenological Psychology

The main problem with behaviourism from an experiential perspective is precisely its exclusion of experience. It objectifies behaviour as readings on dials without allowing for the richness of subjective experience, or indeed the existence thereof in any real sense. It might perhaps be just as valid, or invalid, to start from an analysis of the essential facts of consciousness, rather than from this analysis of behaviour. In fact, let's invert the whole picture (schema). Let's start from an analysis of our experience, setting aside (bracketing) even the existence of the external world for the moment, and on the basis of this analysis derive the formal structure of mind. In other words, what must the structure of mind be in order for the objects which we experience to exist in the form that they do? In chapter 1, we noted Merleau-Ponty's account of what perception must be in order for cognition to occur at all in the first place, and pointed out that it was a phenomenological exercise.

It stressed embodiment, agnosticism on the mind/matter issue, intersubjectivity and a world which had meaning associated with it for the person. It tries to ground its account at that level of experience at which there is no distinction between subject and object (see Nolan, 1992). What we need to do now is draw out some of the

psychological correlates of this viewpoint, and the psychological research which it can involve. We note also the difficulties it has and how they can be sorted out to some extent by the computational metaphor of cognition.

First of all, a sad story. Edmund Husserl, at first sight, seems something of a failure, in that both his early "psychologistic" and later phenomenological projects ended badly. This was not through any lack of brilliance on his part; his work throws up a vast amount of insights. His first project attempted to reduce mathematics and logic to psychological processes in the manner we criticized in section 1.1.4. The conclusion that this reduction is impossible Husserl found convincing. However, Kant's proposal that cognition could only be treated by having the content of experience modified by the categories was one which Husserl could not accept. In his second, phenomenological phase he was far more inclined to attempt to unearth the nature of these formal systems by examining how these other contents entered his consciousness.

We will meet Edmund Husserl again in his incarnation as an AI skeptic in chapter 5. However, he eventually became stumped by the fact that their entry into his consciousness varied in nature as the contexts in which this entry occurred changed. To see a chicken in a farmyard is one thing; to see a chicken on someone's head quite another. Moreover, it is impossible to become aware of the precise computational steps by which we build up objects of any description. The former problem is one phenomenology shares with AI; the latter problem is one where AI can greatly assist phenomenology in building a science of Cognition.

Yet the fact that phenomenology allows data from the precise analysis of consciousness liberates psychology to make fine distinctions in experience. For example, there is a difference between the color red as paint on a wall (volumic red) and as fire (emissive red). Moreover, we can allow ourselves to study in detail the psychological structure of concepts which we know from our experience exist. For example, Michotte's (Thinès, 1977) work on causality varied the circumstances in which one object was seen to push another systematically and noted whether Ss attributed the movement of the objects to the pushing cause. The condition for attributing causality were thus specified. This type of influence on the basis of a controlled experiments we call transcendental deduction: we arrive at a conclusion concerning the nature of the human mind from carefully controlled adjustment of experimental conditions coupled with analysis of Ss' response. Transcendental deduction is valid also in the Kantian framework.

The phenomenological position allows us to consider also the troubled question of human action. We agree that people are active with others in a world with intentional significance (i.e. a world which is meaningful, or in which we seek meanings). Part of this significance is the fact that we are attuned to moral decision, and cannot in fact avoid it. Moreover, we can distinguish here between experience which is actively directed outward to an external world (authentic existence) and experience which is not (autistic or inauthentic existence). The gaps we have noted in Husserl's work still stand: however, we'll find that we can fill some of them in using computational ideas and that the phenomenological account raises questions which only it can answer. As

such, it must be seriously considered in any final theory of Cognition. (Nolan, 1992, gives another description of phenomenology.)

2.1.3 Cognitive Psychology

Perhaps this troubling problem of subjective experience can be handled in another way. In the incarnation of Cognitive Psychology (CP) as Cognitive Science, we find ourselves explicitly equating the brain with the computer, and mind as programs running on the computer (see Introduction). However, CP had a long and mainly honorable history before computing, though it played second violin to behaviourism in most Academic institutions until the sixties of this century. In its CS incarnation, we sometimes find ourselves, probably mistakenly, equating processing of internal representation of the world with subjectivity.

However, such researchers as Bartlett, Piaget and Wertheimer were willing to grant a major causal role to mental computations long before computing was either profitable or popular. We discuss all of these researchers below in the section on memory. The problem of how to persuasively base the speculations of these researchers (active from the 1920s onwards) on firm, tenable foundations awaited computing. The concepts current in their time were not quite hard-nosed enough for the perceived requirements of a psychological science. As mentioned, we discuss the major concepts of Cognitive Psychology in the memory section.

2.1.4 Depth Psychology

Concurrent with the trend toward experimental epistemology in the late nineteenth century, a different line of approach was taking off. It emerged essentially from psychopathology, the study of neurotic and psychotic behaviour. It has given rise to the secular religion of psychoanalysis, and in doing so acquired a bad reputation. We have seen that Herbart and Helmholz had already formulated a notion of unconscious (mainly computational) processes in perception. It was left up to Freud and his followers to complete the notion of the unconscious.

Freud's original work as a physician led him, after an unfortunate period of eulogizing cocaine, to study with the hypnotherapists Charcot and Breuer. Among the symptoms which were noted was "glove paralysis," a paralysis affecting only the area of the hand. Already, enough neurology was known to debunk any physiological explanation for this: it had to be a neurotic symptom. Freud spent a lifetime plumbing the depths of the psyche to discover the origins of such neuroses.

We allude to Freud's theory as a theory of learning, and forgetting, in section 2.4.4. For the moment, let's note that his central concept was that of the libido, or life-force, of which sexuality was but one manifestation. The libido expressed itself through different channels and zones of the body, as development progressed. It might find that an object in the external world offered release of tension. If so, it became "cathected" to that object. Primary process thinking released tension by producing an image of that object: secondary process found the person engaging himself authentically with the world in order to achieve it.

Sometimes the taboos of the family or society in the large (e.g. on incest) forbid even thinking of the object. Then the going gets complicated. Up to now we have been exercised to explain motivation in a way which could be easily handled in an experimental epistemology. The person may attempt to conceal their desire through the object by displacement (e.g. developing a lollipop obsession), reaction formation (hating the object in question) or whatever.

What was common to all neurotic symptoms was that they could be cured only by plumbing the depths of the unconscious. One method was the analysis of dreams, the "Royal Road to the Unconscious." Another was getting the patient to speak unthinkingly (free-associate) until the emotionally powerful matter emerged. Freud's phenomenology of mind proposed that the psyche comprised an energy system (Id), a conscious self (Ego), and an unconscious moral principle (Superego) which blindly took in (introjected) the moral imperatives of the society. It was assumed that energy had to be conserved (Freud lived very much in a world of Newtonian physics). The Ego could put its life-plan into motion only by stealing energy from the Id.

Jung parted from Freud on the issue of the nature of the Libido. He insisted that the psyche needed food of a nature other than the purely physical: it digested also the common cultural and spiritual experiences of mankind as expressed in its culture (archetypes).

For example, archetypes can be expressed in myths like those of Oedipus, Tristan and Iseult or indeed any of the classics. These myths had at least a twofold role: not only were they to play on psychic structure in a way which would help integration into the society in question, but they were conceived also as introducing the person to ultimate concealed reality, the "mysterium tremiendum." The prevalence and power of myth pre-empt the possibility that it can be dismissed in any meaningful theory of Cognition.

Nor can the motive of the work of our third depth psychologist, Alfred Adler. He was wont to see human motivation primarily as striving for power, particularly over others. In this he was following the philosopher Nietzsche (whose epistemology is not really developed enough to be taken seriously). Even an illness, according to Adler, is an attempt to acquire increasing power in the family through the attention one gets. If conceived as a process of requiring increasing mastery over an environment, the power motive is an informative one, and likewise one which cannot lightly be dismissed for our cognitive theory.

Consequently, the going has become a great deal more complicated for us. We can dispute the details of Freud's account of the libido, but never the fact that there are unconscious processes which subvert our attempts to treat memory as a two-dimensional blackboard which can be looked at straightforwardly. Orthogonal to this blackboard are unconscious structures which, independent of our volition, write some items on it and erase others from it. Moreover, we have in Freud a worked-out theory of how libido motivates one to take an interest in the external world in the first place. In Jung, we find an inevitably intricate, convoluted description of the symbols which constitute archetypal experience. Jung is trying the extremely difficult task of objectifying experiences whose external symbolic expression is the map, rather than the

terrain of their lived experience. We see this in the discussion of myth in section 6.2. Finally, Adler at least does us the service of explicating what the organism's drive for greater mastery of the environment may correspond to at the social level. We sometimes label a similar drive "cunning."

2.1.4.1 On the role of affect in cognition

But wait! Haven't we left CS far behind? Science requires some kind of objective tough-mindedness; we're apparently examining entrails in the forlorn hope of making useful predictions. Psychoanalysis and all that: that's all feelings, and everybody knows that they're ephemeral, subjective and certainly irrelevant to cognition. Well, not quite everybody. In fact, a philosopher called Ronald de Sousa (1987) actually went so far as to write a book called *The Rationality of Emotion*, the title of which, as he explains, was assumed to be a joke, or an oxymoron. One hundred and twenty thousand closely argued words later, one is rather convinced by de Sousa. Let's attend to his viewpoint. If he's correct, and emotion is of cognitive importance, then CS has been ignoring a lot of critical data.

De Sousa's criterion for rationality is success: if emotion can help us function more effectively in the world it must be regarded as successful. Consequently, rationality subsumes both truth and objectivity, both of which are subordinate to it. How can emotions, in all their variety, help us in any way? De Sousa (1987, p. 171) refers to the frame problem, Berkeley's formulation of which we examined in 1.1.3. I sit at a desk typing on a Sparc 1. I am in Ottawa, Canada, it is –10 degrees outside, and I just spilled some coffee. So what? Well, let's try and work out some consequences of this. If the network crashes, I might lose my book. If Québec's terrorist FLQ reboot, they are likely to start in Ottawa. The coffee might jam up the keyboard, and so on. In fact, I am attending to changes in none of these underlying processes, though any of them might become of paramount importance. The frame problem at this level is the problem of significant change. De Sousa sees the cognitive role of emotion as ensuring that one remains focused on the task in hand. In this role lies its rationality.

Put another way, how do we know that information is relevant or otherwise until we retrieve it? De Sousa (p. 203) sees emotions as "adjusting salience among objects of attention, lines of inquiry and possible inference patterns." They "supply the insufficiency of reasoning" (p. 195). However, I spilt some coffee on my new clothes and I'm getting a little petulant about that. Surely this negative emotion disproves de Sousa's contention in itself. What could the cognitive role of such an immature response possibly be? It is here that the role of emotional education enters. Emotions derive their semantics (their relationship to the world, in this case), from "paradigm scenarios" – characteristic responses to objects in particular situations. Children are taught the correct responses to objects as diverse as canine excreta, carrots and football. Once the responses are taught, the adult can give a name to the emotion which the child associates with the situation thereafter. De Sousa, I think correctly, argues that this process of emotional education can continue throughout life. He goes as far as to propose a general rule, which is to let your emotions be appropriate to the widest possible range of appropriate scenarios. For example, one's attitude to prostitution

should not change in different contexts, e.g. one of simple exploitation by client or prostitute, or one of social work.

All this is very much worth the detour. CS badly needs a well-worked out theory of emotion such as that supplied by de Sousa. A recent good example of how pressing this need is was supplied recently by Herb Simon's (1994) foray into literary criticism, where he attempted to show that CS in its current state had much to offer Lit Crit. There is one particularly striking line in this essay, where he claims it's unnecessary to propose a formal definition of emotion because we have all experienced it. Really? We all have also amply experienced vision, problem-solving, cognitive development, reasoning…. In fact, it's beginning to look as if we don't have to treat anything in CS formally. The treatment of affect must be put on as firm a basis as any other causal factor in cognition (see O'Rorke and Otony, 1994).

2.1.5 Interlude: the framework here

Nolanism as psychology accepts the primary reality of experience. The vehicle which comes closest to fully expressing this as a theory of Cognition is phenomenology. Consequently, in accordance with this position, we accept the mundane reality of embodied, intersubjective experience as primary. Yet this does not in the slightest preclude any of the following:

1. The possibility of learning by forming bonds between stimuli and reinforcements, either in the operant or classical behavioural traditions.
2. The existence of hidden depths of psychic life best expressed (as they historically have been) in myths and archetypal symbols.
3. The existence also of unconscious fast computing processes which form the elements from which our higher level perception and cognition can emerge.

With phenomenology we distinguish between autistic (inauthentic) experience, and authentic, intersubjective experience, which simultaneously reveals the reality of both one's psychic world and the external world. We assent also to a dimension of egocentric perception/cognition. Finally, we must keep an open mind (!) for the reality of experiences which seem to reveal a transcendent Reality and/or selfhood just as one's mind must be open to the possibility of reductionist explanation of all experience.

2.2 Methodologies in Psychology

We now draw the ideas on the valid data for psychology together with ideas on its valid framework by prescribing the types of methodology which are valid therein. More than any of the other disciplines within Cognitive Science, psychology is dependent on controlled experiment. However, there are other methods used which also generate acceptable data.

The first such is naturalistic observation. This may involve observing, in the manner of Piaget, the development of children through different hypothesized stages of cognitive prowess. Alternatively, it might involve observing the behaviour of a computer program which implements one or other theory of mind. Related to naturalistic observation are correlational studies. For example, students who perform

well in IQ tests also tend to perform well in exams. The trend in intelligence testing has been to assume a direct correlation between IQ and academic ability. This example, however, shows both the strengths and weaknesses of correlational studies. The obvious conclusion seems that one's IQ is a causative factor leading to success or otherwise in exams. However, the IQ test was actually originally designed by Binet using success in exams as the criteria for scaling the IQ factor in the first place! In other words, the problem of cause and effect can be a great deal more complicated than it immediately appears.

Not so with the full rigors of experimental method. Here, the normal set-up allows one to isolate the precise effect of a single factor. For example, we might wish to determine the effects of alcohol on memory. We set up a task (for example, remembering a list of phone numbers), an agreed dosage of alcohol, and divide the Ss into two groups. The experimental group consume the required level of alcohol, the control group none. We then can objectify the effects of alcohol in terms of success on the memory task. The objectification in question could also include factors like reaction time, or indeed anything measurable in this sense.

We looked at the technique of transcendental deduction above and found it could be used in phenomenological psychology. Let's observe it now in the more straightforward Kantian framework which is its natural habitat. A well-known experiment by Saul Sternberg involved Ss learning a list of single-digit numbers e.g. 1, 3, 4, 5…. The list was presented for just a second. After a two-second delay, a single digit was presented and the subject had to decide whether it was on the original list, signaling the decision by pulling an appropriate lever. The aim was to discover what scanning method the Ss used. There were several different possibilities:

1. An image including all the digits in question.
2. Scanning through the list until the digit in question was noted and then stopping.
3. Scanning through the whole list, continuing even after the digit in question was noticed.

Now, each of these hypotheses (1)–(3) leads to different predictions and can thus be directly tested. If (1) is correct, the position of the digit in the list should not matter for the speed of reaction (i.e. pressing the lever) nor should the length of the list be an important causative factor. As it turns out, (3) fits best with the experimental data. We have Kant's program of transcendental deduction given experimental flesh and bones in this type of experiment.

A similar experiment is Sperling's test of the memory trace. In this case, a large array of letters were momentarily flashed in front of Ss:

A G U S
T A I M
T I N N

If Ss were asked to list them afterwards in total ("whole report"), no more than four or five could be remembered. However, if Ss were cued (perhaps by an appropriate tone) the instant the display was turned off as to which row they had to list, an average of

more than three could be remembered. This indicates that at least nine of the letters were available in some kind of short-term storage (iconic memory). A similar situation seems to hold for hearing (echoic memory). In short, it seems we process vast amounts of data in the first instants after perception and these data fade extremely quickly. We shall have more to say on this below.

A further method is an extension of naturalistic observation to allow formal experimentation. For example, we've noted that it is valid simply to examine the input-output behaviour of a computer program which simulates a cognitive process. We might find it possible also to vary the input and note corresponding co-variance in output (see section on equivalences in chapter 1). Alternatively, we can study an elaborate cognitive process like language and try to decompose it into elements (see chapter 3).

We also might find it necessary, particularly in the case of language, to appeal to another source of evidence i.e. "native speaker intuitions." Lacking, as we do, a Grand Unified Theory (GUT) of Language, or a single comprehensive Grammar even for our lingua franca of English, we find it necessary to ask the domain experts (i.e. speakers of the language) whether sentences are grammatical or not as the only possible usable criterion. Moreover, we find it necessary to distinguish between these speakers' hypothesized knowledge of the language, as expressed in comprehension (their "competence"), and their often faulty (due to tiredness, information overload, etc) production "performance." This hypothesized perfect linguistic structure is quite near to Plato's concept of Ideas and their incarnation in the human mind. Moreover, like Plato's slave-boy in the Meno, every human has this vast competence.

For the reasons given in the history section, we have omitted introspection. However, the type of phenomenological analysis achieved by minds as acute as Merleau-Ponty must also qualify as a methodology. The type of data which they report must also be included. Again, the main criterion has to be consensual validation. We have not yet constructed a truly objectivist scientific psychology (and perhaps it is both impossible and undesirable). In order to ensure that we are catering for all the facts of mental life, we must allow data which, though collected experientially, are universal.

2.3 Perception

2.3.1 Perception and Cognition

The distinction between perception and cognition seems initially as well-defined as that between seeing a tree and thinking about a crossword clue. However, things are in actual fact a great deal more complicated. In this section on perception, we discuss several different schools, each of which has a distinct viewpoint on the perception/cognition issue. On the one hand, we're going to note that J J Gibson's school of "ecological optics" assigns to perception a lot of the higher-order informational process which might at first blush be considered the province of cognition; on the other, the constructionist account grants to perception only the task of supplying an informational characterization (in terms as basic as the binary code which computers use) of the scene viewed, with cognition supplying the mechanisms truly to process the scene, extract objects, etc.

Related to this issue is the extent to which perception affects cognition, and vice versa. In a famous set of observations, it was noted that pygmies who grew up in jungle environments without sharp edges failed to interpret photos, seeing black and white photos only as shades of grey (see chapters 6 and 7). Is this a perceptual problem, a cognitional one, or a problem of their interaction? Likewise, our language might predispose us to make certain fine distinctions in our environment (see chapter 3) which are not immediately salient for speakers of another language. One Northern American Aboriginal people (the Inuit) famously has about 14 (admittedly compound) words for different types of snow. Has cognition now affected perception?

We've noted that perception in Merleau-Ponty's schema is the background for acts of mind. Let's look at two other possibilities for characterizing the perception/cognition relationship.

1. Perception is that which delivers the data on which cognition acts computationally (the constructionist account).
2. Cognition involves acts which are conscious, or potentially conscious (remember our account of eye-focusing as the latter in chapter 1). Perception involves unconscious informational processes.

Therefore, such processes as syntactic parsing (section 3. 4.3) are perception according to account (2) and cognition according to account (1).

In fact, the debate is ultimately quite pointless. What matters is that somewhere in the long, intricate path from sensation much computational processing is being done. Whether this is called "perception" or "cognition" is really irrelevant. There is one sense, however, in which we could possibly use the distinction. We could reserve "perception" for acts which explicitly interrelate the subject and her environment, and cognition for (usually conscious) acts which allow the subject to transcend her environment by making plans. These plans, in turn, may explicitly involve changing the environment. (I use this terminology in chapter 9). We can then add that acts that formerly were cognition can become subsumed by perception. Let's consider tuning an instrument. It normally requires a conscious act of will for a beginner to detect differences of anything less than a quarter-tone or so. Yet, once sensitivity enters the habitual structure of one's mind, it seems appropriate to place it more toward the perception than the cognition end of the continuum.

For some cognitivists like Jerry Fodor, this type of schema is unacceptable. We noted in 1.4.5 that he insists on certain insulating attributes of vertical modules, specifically that they be domain-specific and informationally encapsulated. Perception is the province of these dumb, mutually independent vertical modules: cognition is the realm of a central system. In fact, as Jackendoff (1987, 271) points out, Fodor goes to great lengths to separate the two. The reason seems to be to allow valid (veridical) cognition, immune to perceptual illusion. My feeling is that the burden of proof is very much on Fodor's side here. In order to establish his system, he needs to catalogue these modules (e.g. phonology, syntax), demonstrate their encapsulation, and indicate what is left for a central system to do. He then has to prove that no top-down influence from this well-defined central system to the vertical modules exists. Moreover, some of these

modules are going to be multi-modal. For example, motion data is represented with the aid of interactions between visual and somato-motor data (Trotter and Burnod, 1992). Head movements are registered by a variety of sensory modalities, including the vestibular. From an early age, children show ability to transfer knowledge learned in one sensory modality to others (Streri and Lécuyer, 1992 show that from the age of two months, children can visually recognize objects previously only touched). The lack of top-down influences seems even harder to demonstrate: in vision, to take one example, the number of neurons carrying messages from central to peripheral areas of the cortex far outnumbers the reverse. We noted in 1.4.5 that the modularity thesis in its undiluted form doesn't even allow reading.

The form of modularity which seems tenable is at best one which allows modules to work across different sensory modalities, be identified with translation processes like those which integrate at the syntactic or phonological level. In fact, Jackendoff (1987, pp. 271–2) sees in this a way to allow greater freedom for cognition/perception interaction than Fodor will allow. Undoubtedly, some of Fodor's notions like those of encapsulation and domain-specificity are useful. However, it does seem that risk of trivialization is always there. More importantly, in the absence of the volumes of corroborative data which Fodor lacks, it seems worthwhile to continue doing CS in the hope of a more adequate theory of mind emerging.

2.3.2 Transduction and Encoding

Whatever one's position on the perception/cognition question, one must accept a separate stage at which incoming patterns of energy are converted (transduced) into patterns of neural impulses which accurately encode the objective events mapped by the sense-data. The precision of the encoding depends on the requirements of the organism. The human capacity for color vision is not shared by lower animals: conversely, bats are attuned to auditory frequencies which we humans will never hear. The palette of our sensory experience is structured initially by the evolutionary needs of the organism and secondarily in the human case by cultural development. For example, painters can detect gradations of color which non-painters cannot.

Let's focus for the moment on the bare facts of transduction. Sense-organs are cells spread over areas of the body which are specialized for the conversion of specific patterns of energy flow into neural event. The main senses are the visual, auditory, olfactory (smell), tactile, gustatory (taste), heat and various interoceptive and proprioceptive senses. Interoception focuses on inner sensation of the process of digestion. Proprioception involves feelings of movement (kinesthesia) and features feedback from muscle systems in particular.

Much of the data used by sense-organs is mechanical in nature. Obviously, touch and kinesthesia involve purely mechanical data. More surprisingly, auditory data is mediated by mechanical means. Sound comprises energy bursts which propagate through the air (or with less ease, other media such as water) as longitudinal waves. These bursts cause the eardrum to vibrate (see diagram 2.1). The vibrations are transmitted through the bones of the middle ear (hammer, anvil, etc) before reaching the basilar membrane. At this point the frequency of original energy burst is now being

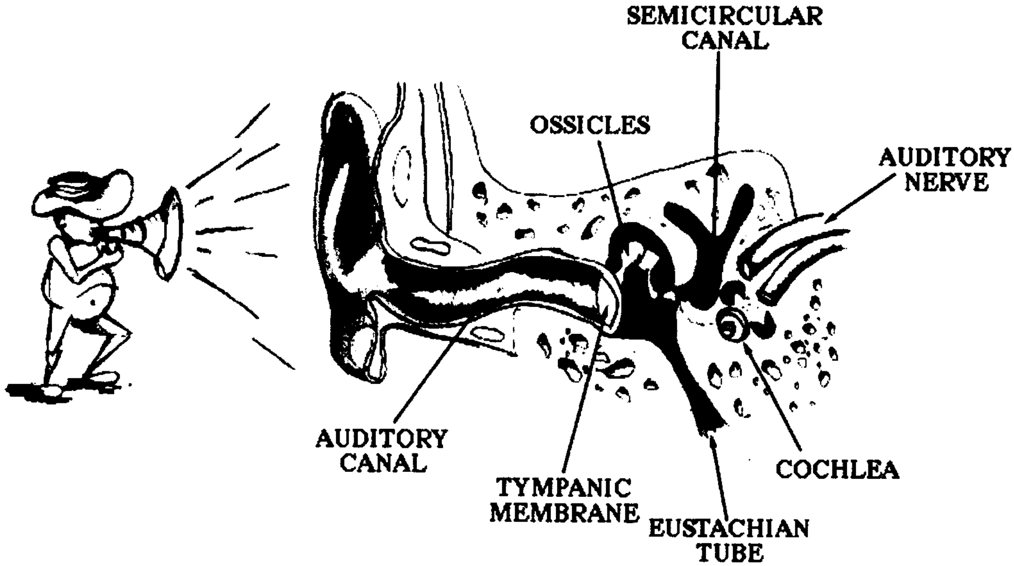


Figure 2.1

articulated as movement of fluid. This movement in turn causes hair cells to shear, resulting in bursts of neural activity which are processed in the cortex.

In vision, however, the process is quite different. The hundred million cells in the retina (see diagram 2.2) divide into rods and cones, which respectively cater for black/white and color vision. Essentially, the transduction involves light falling on photosensitive material and electrical discharge causing neural activity. Moreover, a great deal of computation is going on at the retina in order to detect objects in the stimulus array. The outlines of objects correspond to points of maximal change of light intensity. At the retinal level itself, without any reference to higher cerebral activity a process (analogous to using the Laplacean operator on a two-dimensional Gaussian distribution) implements detection of the outlines of objects.

The data are quite different for the other senses. The major point of interest with respect to cerebral activity is that, in general, sensations which are close together in their energy profile have contiguous encodings in the cortex. The exception to this general rule seems to be olfaction, where the representation more closely resembles the "formal" neuron systems used in connectionism (see chapter 4). "Topological mapping" is the name we give to the general rule.

Encoding is the process whereby properties of the initial energy patterns are preserved in neural impulses. Now that we've left transduction, the going becomes a lot more controversial. J J Gibson would play down the encoding and higher cortical stages on the basis that the information is already there in the sense-data. We'll see that his analysis involves redefining the stimulus to involve structured sensation over time.

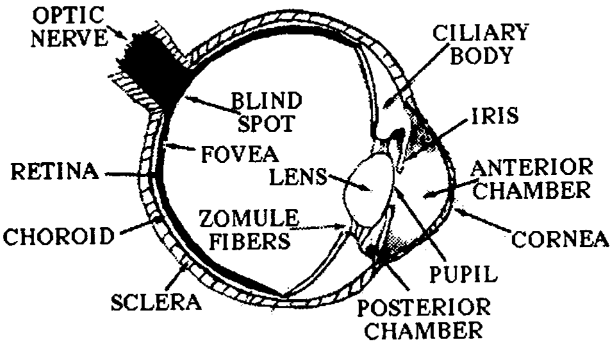


Figure 2.2

For example, the stimulus for Gibson is the sum of the varying perspectives on a chair as one moves around it.

Gibson's argument can be extended to explain other perceptual constancies. We manage to maintain in our minds the real size of a football even as it is travelling very quickly away from us (size constancy). Gibson would argue that this realization is no longer paradoxical if we bear in mind that the stimulus is the football moving over time in a certain context. Likewise, shape constancy holds for the chair we keep referring to. Color constancy is the fact that a car will somehow contrive to seem much the same color under sodium light as in broad daylight.

The major uncontroversial point in this section, then, is the process of transduction from energy bursts to neural impulses. We can mathematically simulate this process by use of the Fourier transform. Fourier's theorem states essentially how any regularly occurring oscillation (like speech) can be mathematically mapped. Having done this, we have a tractable description with which to work computationally. We must bear in mind, however, that we lack much of the biological equipment with which nature simplifies these tasks.

2.3.3 Ecological Optics

The work of J J Gibson, the founder of this school, is enjoying a new lease of life in Artificial Intelligence studies of vision. His study of such matters as optic flow (how perception of the texture of one's environment changes as one moves), seems in retrospect to have great heuristic value. Gibson's work is also extremely hospitable to the Mylesian viewpoint. Let's go through its main points.

First of all, Gibson stresses that the proper object for psychological study is the organism plus environment regarded as a single system. We've come across this point before in that we've established that mind can be studied only with regard to such a system, and we've added that we also have to study the development of organism/environment interactions. I wish to flag how central this thesis is: in Piaget,

we're going to discuss it as cognitive psychology; in neuroscience, as Neural Darwinism (i.e. the notion that groups of neural processes compete with each other to have intercourse with the world, with only the winning group surviving to do so). Finally, even with respect to the psychology of selfhood, we find a need for such an encompassing view of subject/object relations.

The organism is thought of as attuned to objective properties of the environment, rather than being driftwood in a tempest of stimuli. Let's take Berkeley's Frame Problem again. I move around the room, and my perception of my desk continually changes. How can I extract the desk itself from this flux? Let's change the issue completely, because this problem is almost intractable. Surely the stimulus which I process is actually the changing array of sensations spread over time? Is it not reasonable to assume that there are higher-order invariants which remain constant despite the dance of input data? In fact, Gibson devoted his experimental work to characterizing these invariants: one such set was connected with disappearing objects.

It's obvious that Gibson's position is analogous to philosophical realism. Objects are assumed to produce likenesses of themselves in one's brain in some sense directly (see diagram 2.3). The notion of objects being mediated by representations of themselves in the brain which structure how they are perceived is abandoned. We end up with Cartesian paradoxes if we posit the existence of these representations. There are obvious philosophical difficulties with realism, in that we find ourselves asking whether all possible perspectives on an object are equivalent objective properties of that object. In particular, how can error then occur? In psychology, we find ourselves asking how illusions such as the Müller-Lyer illusion (where two lines of equal length are perceived as being of different length because of context) can occur, if we are so perfectly adapted to our environment. Gibson's answer to the problem of error is that it normally occurs within peripheral, as distinct from focal vision; in distal, as distinct from proximal perception. Illusions he dismisses as artifacts of contrived experimental set-ups which separate the organism from its environment.

The organism is not conceived of as particularly active in perception. It may for reasons endogenous to (within) itself, decide to pick up one type of information rather than another at one speed rather than another. Quite simply, if hungry it will look urgently for food. In the case of vision, the information is all there, objectively, in the light itself and endogenous factors do not affect it.

In view of Gibson's (1966, 1979) lack of explicit reference to philosophy, the parallels with Merleau-Ponty are striking. For Merleau-Ponty and other phenomenologists, the world for the subject is as full of meaning (affordances) as it is for Gibson. Both groups also insist that three-dimensional space is not constructed by the subject, but given from birth. Gibson also refuses to make mind/matter distinctions, and likewise will not comment about mind in the abstract apart from an environment. In fact, we end up with a schema where again the problems of perception and cognition are inextricable from consideration of Being-in-the-world.

Like Merleau-Ponty, Gibson has difficulty in providing a comprehensive framework in which his brilliant work on the analysis of perception can be combined with a coherent view of higher-order cognition. In Gibson's view, all potential uses of objects

are said to be directly afforded. The pen affords writing, the car driving. A reductio ad absurdum of this viewpoint might claim that therefore blank sheets of paper should afford composition of *War and Peace*. It is here that the Mylesian framework attempts to redress the imbalance. Gibson's perceptual work, like Brook's Mobotics in chapter 5, is conceived of as a brilliant analysis of Egocentric mentation (working of mind). The intersubjective level requires a different set of concepts.

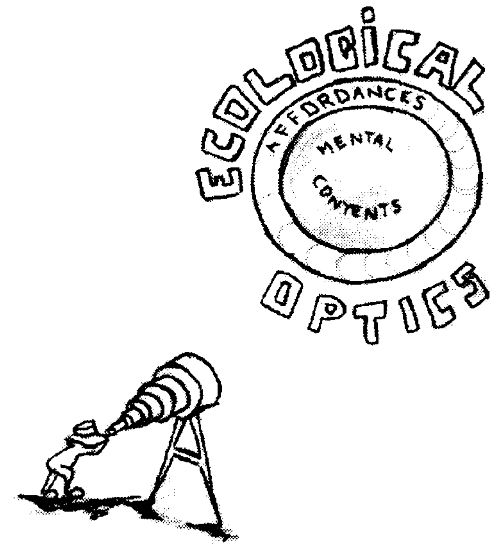


Figure 2.3

It was assumed by many perception scientists that Gibson's work was a heuristic dead end, due to the alleged difficulty of experimental design which it provoked, and neurophysiologically implausible. Both charges should be dropped. Gibson's framework insists that invariants should be described. But this is very much an empirical task at which he himself made much progress. On the neurophysiological level, it may seem at first glance implausible that objects can radiate impressions of themselves which inform the structure of processes in the brain. However, Karl Pribram's holonomic theory, which we outline in chapter 4, allows the Gibsonian framework a neural reality. For Pribram, perception involves a coming into synchrony of the microprocesses of the brain with the activity of particular sense-organs. Pribram allows that this synchrony may be mediated through action at several different levels (rather like Dyer's schema, which we explore in the section on Connectionism in chapter 4). He insists that a transformational realism of this sort is neurologically plausible and does violence neither to the integrity of brain science nor to the realist ethos.

Let's conclude by noting that Gibson's seems an extremely valid framework for egocentric mentation, and compatible both in its ethos and its specifics with Merleau-Ponty. Likewise, Gibson shares the French phenomenologist's difficulties of encompassing symbolic and perceptual mentation in a single framework. So far as their work is testable, it has in fact been verified. Children seem to have an intuition of 3-D space as early as can be ethically tested (Streri and Lécuyer, 1992); their ocular movements (but not control) for object tracking are formed early, and higher-order invariants do exist. However, children's symbolic behaviour takes longer to develop and for that type of behaviour we need to look at the work of Piaget.

2.3.4 The Gestalt approach

We're going to find in our discussion of problem-solving that the Gestalt approach has much to contribute to debate in that area. For the moment, we'll focus on what it has to

say about the processes normally labeled "perception." In the first place, Gestalt (whole/group) psychology focuses on whole-qualities in perception. Take, for example, our perception of the figures in diagram 2.4 (a pub variation of the Kanisza triangle illusion): we cannot but see them as an incomplete circle, triangle or star, rather than as a chaos of elements. Moreover, imagine Brahms' first symphony being played in D minor rather than its normal C minor. What's the difference between the two performances? Well, none actually, apart from that due to the specific qualities of the instruments. The "whole property" which dominates our hearing of the themes of the symphony (or indeed any melody, irrespective of the key to which it is transposed) takes precedence over the details.

Moreover, the Gestalt school argues that it is only with reference to whole-properties that many apparently psychologically elementary processes have any meaning. We cannot even talk of generalization, a crucial concept for behaviourism, without some notion of a whole quality. Let's imagine that a Pavlov dog has learned to salivate to a tone of 256Hz. A tone of 240Hz is sounded and the salivation again occurs. In fact, it is found that generalization works for a large segment of the auditory spectrum. Gestaltists argue that even this shows a degree of concept-formation, of the appreciation of a whole-quality. Perception is seen as governed by laws of Prägnanz (good organization) which, for example, can correctly command the "closure" of the rectangle and circle in diagram 2.4.

The attack gathers even more force when directed at problem-solving, as we note presently.

2.3.5 The constructionist approach

This approach insists that we construct objects from a chaos of shifting impressions. We have noticed time and again the paradoxes to which this leads, both with respect to the Frame Problem and the Cartesian homunculus. Perhaps the failure of AI systems based on constructionism is the most telling argument against it: we dwelled on this point in section 1.2.

2.4 Memory

We cannot ultimately separate memory, learning, the flow of consciousness, problem-solving and indeed identity which is bound up to a large extent with one's lived experiences. Each single mental act involves many past such acts. Similarly, the field of consciousness for two individuals with identical external stimuli may be completely different. Their memories structure their experiencing these stimuli in ways which result in vastly different subjective experience. An example to which we keep returning is the difference between a novice's and an expert's experience of music.

As mentioned above, we are going to look at memory from a range of different perspectives. First of all, in what sense is memory a storage area, and what kind of store is it? Secondly, we talk about memory and learning. Thirdly, we ask how we can creatively best make use of our lived experiences in problem-solving. We mention behaviourism in passing. Fourthly, in relation to this, we ask whether there are patterns to forgetting, to the inability to solve problems whose successful solution forms part of

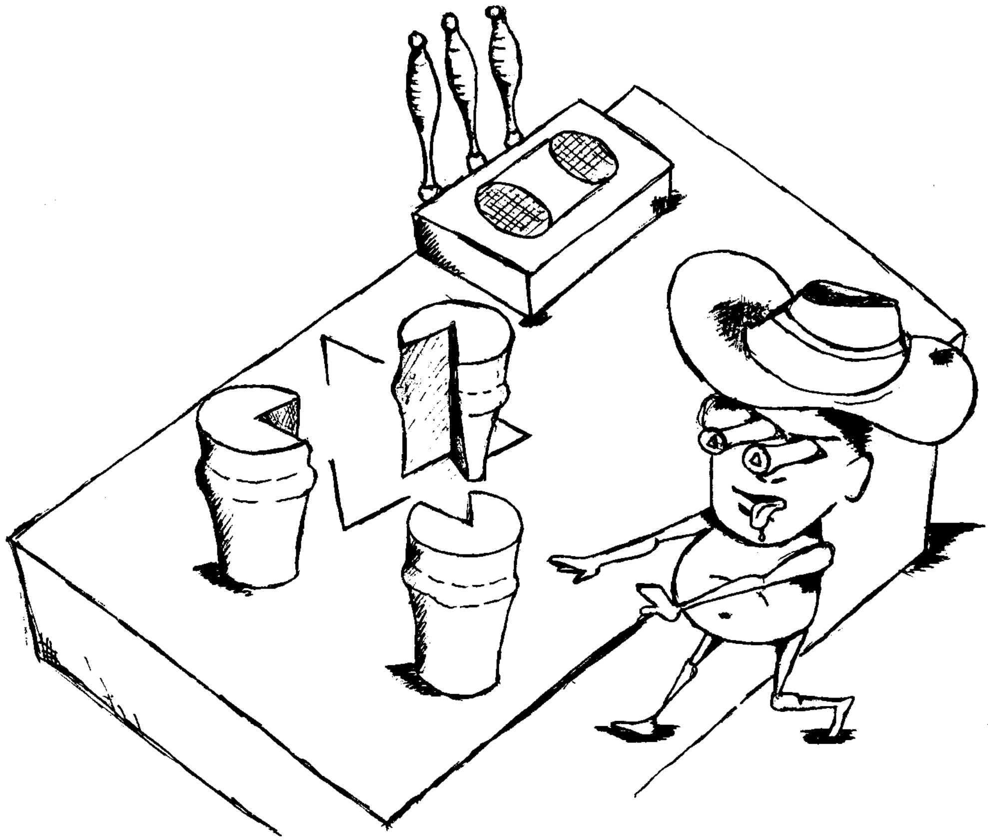


Figure 2.4

our past experience. Finally, we ask to what extent we are our experiences i.e. to what extent are we similar to others who have experienced similarly? This question has been partially addressed in chapter 1; it will occupy us also in chapter 8. (Luria's (1969) portrait of a man forced to remember everything is worth investigating).

2.4.1 Memory as a store

When viewing memory as a store, a computational metaphor is extremely useful. In computing, we make a distinction between storage media which are potentially removable from the machine like floppy disks, RAM (random access memory) which is the primary workspace of the computer and ROM (read only memory) which contains a few commands without which operation of the computer is impossible (COPY, DIR, etc). Similarly we make a distinction in human memory between long-term memory, conceived of as back-up storage, and short-term memory, which is a workspace. In the meantime, certain ROM commands remain continually present (e.g. don't fall off heights; nothing can be in two places at the same time).

We need also note how our experience is conditioned by our memory of past events. Moreover, as we act on (effect) the world, our directives to our motor effectors have to be informed by feedback from our sense-organs. Sperling's work showed that we process a great deal more data than we become aware of. The filtering process somehow presents a coherent world to us from the tidal waves of data processed. Were we forced to attend to this tidal wave, we would lose our ability to cope. At present, we're concerned with this filtering only in informational terms: . In chapter 8, we ask whether one of the principal cognitive functions of selfhood is actually to maintain a necessary distinction between relevant material (conceived of as meaningful) and irrelevant (conceived of as nonsense, or not even noticed).

Short-term memory (STM) is usually cited as holding around seven items (the seven wonders of the world, the seven tasks of Hercules, a seven-digit phone number). We can up its capacity, and the informational throughput of the whole system, by chunking. For example, Morse code operators gradually learn to chunk the dots and dashes into letters and these, in turn, into words. STM might also be divided into separate processes for linguistic and non-linguistic knowledge. Ó Nualláin (2000b) contains a paper by Pearson et al indicating that perhaps the situation is finer-grained still. We note also in chapter 4 the somewhat contested role of the hippocampus and long-term potentiation in memory. However, the notion that a memory is a dynamic pattern that is evoked by a cue to salience is likely to survive. The role of deliberate frontal lobe activity in "elaborative encoding" to enhance LTM is well-discussed in Schacter (1996).

In fact, arguments rage as to whether, and how, all memory can be analogously divided. Is there a visual as distinct from a verbal code in memory? Alternatively, it seems likely that cognition, a priori, is ultimately implemented by unelaborate code of neural impulse (but see below and chapter 4 to get a more complicated picture). Can it therefore be concluded that the "language of thought" is monolithic and simple, the yes/no (binary) answers given by neural firing?

Yet another possibility exists, and it is the viewpoint taken here. The brain, in its attempts to maximize adaptation of the organism to its environment, is willing and able to implement systems from a whole spectrum of different possibilities. These include visual (Kosslyn, 1994) and verbal codes, purely propositional (e.g. yes/no) codes, codes which use spreading activation (by tagging neural impulses with cues as to their purpose and effectiveness), and purely symbolic systems. ("Codes" is used in a broad sense here to include systems of production and transformation of representations.)

The evidence at the moment for the "multiplicity of codes" hypothesis comes from observation of the "tagging" type of neural firing; observation of the development of vision in infants, which shows an opportunistic quantum leap from a probabilistic guess to a pure symbol at a critical stage; and the implementation of the hypothesis in the connectionist architectures discussed in chapter 4 and in much greater detail in Dyer (1989). Brain science shows a lateralization of verbal/mathematical ability in the left hemisphere and spatial abilities in the right hemisphere in over 90% of those

surveyed. Yet so little is known about higher-level cognition that no final conclusions are near being drawn as to its location.

Effectors can perform extremely complicated memory tasks like musical performance (see chapter 7). Here we have enormously intricate interactions from a variety of sources. We'll finish this section by noting that many of these manual skills are unconscious. It would be impossible to perform music, or even drive a car, being conscious of every moment. The degree to which we can become conscious even of verbal/analytic skills itself varies greatly from person to person.

2.4.2 Memory and Learning

It is generally agreed that it is impossible to study knowledge without taking its development into account (Kirsh, 1991). This goes as much for knowledge manifest in an organism's increasing adaption to and mastery of its environment as knowledge implemented as computer programs. In this section we're going to examine some different statements of the learning process.

2.4.2.1 Innatism

The first such notion states in effect that learning does not occur. The tradition of innatism, dating as far back at least as Plato, holds that knowledge acquisition is simply the unfolding of some inborn structures. Whether these structures are the property of an immortal soul free from the dictates of space and time, as Plato thought, or the protein-synthesis commands of the DNA double helix, as modern day innatists like Chomsky and Fodor claim, is irrelevant to us here. Logically, the claims of the innatist position are independent of the precise implementation of the mental structures postulated (be it a soul, a brain or a computer).

Essentially, innatism contends that acquisition of a concept on the basis of experience alone (claimed by empiricism as valid) cannot actually occur. Innatists insist that the concept must already be there in some germinal form. In other words, it is impossible logically to derive a whole plethora of abstract concepts (set intersection, logical inference, causality, to name but a few) from experience. They must be innate. It will be noticed that most of these abstract concepts are handled by Kant in his notion of categories. Piaget, in turn, argues that even categories require development, but that this development involves species-specific interaction with the environment which is the lot of every human being. Consequently, we have in Piaget a synthesis of the innatist and empiricist positions. The knowledge corresponding to categories is learned through interaction with the environment, but this interaction is inevitable (Furth, 1981).

Up to recently, little was known about the infant's perceptual abilities. For every innatist like Merleau-Ponty who posited a great deal of knowledge being present from birth, an equal but opposite empiricist like Locke claimed contrariwise. It was noted above at the end of 2.3.3 that the current evidence seems to favor precocious abilities at least in the non-symbolic sphere. An early capacity for depth perception was demonstrated by a set of studies featuring an artificial visual cliff by T G R Bower (1979). Young children show surprising capacities for transfer of knowledge between

perceptual modes (e.g. an object previously only seen may also be recognized when being felt and not seen), categorization and casual relations. Similarly, face recognition has been demonstrated in 3-day old infants (de Schonen, Burnod, and Deruelle, 1992).

However, the situation is a little more complicated than this. This type of knowledge is egocentric and shared with precocious animals, some of whom are far advanced of human infants of equivalent ages. Indeed, there may be a strong argument that human infants need to have as few as possible of their behaviours, as distinct from their sensory abilities, set in stone in order optimally to learn later. Children may demonstrate an ability to correlate an image generated by camera tracking of their leg movements with the proprioceptive data thus generated from as early as 5 months. Yet the same children fail to recognize themselves in the mirror until 19/20 months. (Baudonnière, P, J. Lepecq, F. Jouen, 1992)

It seems there is a discontinuity between the development of that egocentric knowledge and intersubjective symbolic knowledge which is uniquely our preserve. We discuss this implicitly while outlining Piaget's theory of development. Whether children attain full adult competence in empathising with another's motives by constructing a priori, in the manner of a scientist, a model of the mind in the abstract or whether they have some privileged access as a result of having minds themselves has exercised researchers like Alison Gopnik (Wilson et al, 1999, pp. 838–840). Like every other attribute, precocity in understanding of motives seems possible. It is impossible to read Sereny's account of the interrogation of Robert Thompson, one of the murderers of the infant Jamie Bulger, without feeling that here was a criminal genius in the making.

2.4.2.2 Freud and Learning

We've already discussed the major outlines of Freud's theory. In 2.4.4 we focus on phenomena like repression which cause suppression of memories. The essential mechanism postulated for the positive process of learning is conceived of as cathexis. The range of objects which are cathected is gradually increased until something like the full adult awareness of the world emerges.

The consequence which we draw from this here is that learning involves affect. The objects chosen have often intricate emotional meanings. Furthermore, they can be chosen with respect to the perceived needs of development of one's self, however this self is conceived. Our cognitive theory excludes affect at its peril. Whatever the ultimate validity of psychoanalysis as therapy, the causal role of affect in cognition cannot be ignored.

2.4.2.3 The Developmental Psychology of Jean Piaget

Jean Piaget was born in Neuchatel, Switzerland in 1896 and died in 1980. His earliest paper, published when he was eleven, concerned the sighting of an albino sparrow. His formation was originally as a biologist, specializing in mollusks. In the early part of this century, a school of philosophy led by the great Henri Bergson (who, perhaps uniquely for a philosopher, had Irish, French and Jewish ancestry) focused on biology

as a possible key to understanding some philosophical problems. Piaget quickly homed in on this approach.

From the biological perspective, knowledge must somehow increase the organism's adaptation to its environment. From the philosophical point of view, to study the development of knowledge in a natural setting seems a priori a worthwhile project. Piaget further argued that this development would reveal much about the essential nature of knowledge, as distinct from just amassing details about the vagaries of its development.

With this in mind, he began to study the cognitive development from infancy of his own and other children. This became his life's work. His first book, *The Language and Thought of the Child* (1926; original French text, 1923) secured his international fame before the age of thirty.

He described his work as "genetic epistemology" and as such it is obviously relevant to cognitive science. His relevance is becoming greater rather than less as the years pass. Piaget's is the only fully worked-out theory of cognition which traces the growth of knowledge from an infantile state conceived of as unseparated from the environment (undifferentiated) to full adult logical competence. We've noted that it is currently accepted that intelligence, whether natural or artificial, cannot properly be studied apart from its development, which increases Piaget's relevance. Moreover, his insistence on viewing the growth of knowledge with respect to the exploration of an environment by an active organism gives his work a new urgency (see the short account of Brooks in chapter 5). He alone this century has had the courage and genius to plot a detailed route from biology to logic.

Not surprisingly, given its scope, many of the details of Piaget's work are wrong. His experiments tended to be badly-designed, using far too small a sample size. Like many others who have tried to replicate him, I've found myself disagreeing with his results, his interpretation of the results, or both. Earlier in his career, as we shall see in 2.4.3.4, he had an unhealthy obsession with logic. Interestingly, he later recanted, and proposed that Psychology pursue an (unfortunately unspecified) "logic of meanings." He failed also to appreciate the autonomy and power of the human linguistic apparatus (chapter 3). Were not his system flawed, there would be nothing left for Cognitive Scientists to do! Let's press ahead with a short description of his work.

A A Glossary of Piaget's Key Concepts

Equilibration: The tendency for an organism to seek both stability and a higher degree of adaptation to its environment. This is regarded by Piaget as the fundamental cognitive drive. Related to it are two more modern concepts: "The Principle of Rationality" insists that the cognitive system above all attempts to maximize the organism's adaptation. ("Autopoeisis" gives a more biological description of the same process (Varela, 1988)).

Assimilation: This is the use of an old action or representation to deal with an object. It is consequently different to

Accommodation, which adapts the cognitive system to the environment.

Decentration: This refers to problem-solution by focusing on an aspect of the problem heretofore ignored for whatever reason. For example, you lose your car keys and you *know* that you gave them to your partner. You spend hours grilling your partner as to exactly when and where you gave them and refuse to budge on the issue. Suddenly you decenter and realize they're in your jacket pocket. This is an example of a type of decentration called:

Subject-object differentiation, where solution is achieved by considering oneself as part of a more encompassing picture, fleeing the egocentric domain.

Structures: These are (mainly) logical systems which are internally consistent and allow the subject to systematically deal with the outside world. Arithmetic is one such system. Piaget criticized the Gestaltists for assuming the existence of such systems without describing their genesis, and behaviourists for ignoring systems altogether (structure without genesis, genesis without structure).

Schemes: These are stereotyped sets of actions which perform particular tasks. A first example of such a scheme is the infant's looking for and finding its mother's breast. They must be distinguished from the:

Schema (plural: Schemata), which is a static memory structure reflecting some aspect of the world. An example is the schema which represents entering a restaurant. We remember that the stereotyped sequence of actions involves waiting to be brought to a table, perusing a menu, ordering etc. This notion was adapted by the Schankian school in its notion of a script (see chapter 5). Bartlett produced an analogous concept.

Operational knowledge: This refers to knowledge which originates from one's physical interaction with the world. It begins with simple actions. These actions can then become internalized. For example, a child might first have to physically move around objects of various sizes in order to put them in order (seriate them). At a later stage of development, it is possible to do this by means of mental manipulation of symbols representing those objects. However, Piaget argues that a further internalization allows mental seriation of seriation, giving the operation of permutation. For Piaget, this kind of development is the essence of cognitive development and can in fact explain acquisition of language and acquisition of mathematics, inter alia. Internalization of actions begets symbols in this manner, which is inadequate for language development (see chapter 4).

Representation: With each stage in the development of operational knowledge comes also a distinct way of representing reality. Initially, the world may be represented only in terms of actions one can perform on it (close to Bruner's notion of "enactive"

representation). Secondly, elementary mental images might be used (Bruner's "iconic" representation). Finally, reality may be fully symbolically represented.

Innatism: We have noted that Piaget provides a via media between innatism and empiricism. He argues that there are certain ways in which a specific species must act upon the world. The knowledge arising from these experiences, though empirical in process, is genetically inevitable.

Conservation: This is almost as central to Piaget's work as equilibration. He argued that at a certain age, which varied from culture to culture but approximated to seven years, a quantum leap in cognition appeared. The child went from conceiving of change as unidirectional and irreversible to its being reversible. For example, Piaget argued that, before conservation, if liquid was poured from a tall thin glass into a broader beer glass, the child would assume that there now was less liquid. With conservation perception becomes informed by abstract notions like mass, length and quantity rather than sensory impressions. Conservation is a milestone in cognitive development: with its advent comes number and a better logic as well as the notions of the last sentence. Let's examine number. For Piaget, it is conceived of as the operational synthesis of seriation and cardination. Until this synthesis occurs, number is inaccessible to the subject. Many of his experiments demonstrated, at least to his satisfaction, that children did not even have part/whole relationships until conservation. When shown a group of both somnolent and active cows, children would answer "yes" if asked whether there were more sleeping cows than cows. Similarly they agreed that there were fewer beads if a row of beads was compressed in length, without taking away any.

Apart from egocentrism, to be presently discussed, conservation status is the most controversial of Piaget's concepts. The "sleeping cows" problem has been debunked as a linguistic confusion. Nobody has managed to get children to perform as badly as Piaget on the mathematical/logical/concept-formation tasks he uses. Yet there is a breakthrough in cognition around the age Piaget proposes, a fact which has remained intact through the voluminous discussion. Where Piaget seems to have erred is in his obsessive attempts to describe it in purely logical terms, and as the advent of a Kantian category. It may be more parsimoniously described as the child becoming able to reflect on her cognitive processes, and detect that they are objectively mismatched to reality. We can describe it as a quantum leap in consciousness, rather than logic (Flavell et al, 1986). The terms of description are examined again in chapter 8.

Flavell's co-author, Eleanor Rosch, produced some much-referenced work on categorization which gives the lie to Piaget's subsumption of it under conservation (see Wilson et al, eds, 1999, pp. 104–106). Before her research, it was assumed by such workers as Quillian that concepts were arranged hierarchically, à la biological taxonomy. However, reaction time studies showed that such hierarchies could not predict certain behaviour: trivially, one recognises that "a robin is a bird" is true faster than "an emu is a bird." Prototypicality was then introduced to structure concepts. Secondly, Rosch distinguished between "base level" concepts, which normally involved certain physical actions, e.g. sitting, defined on them; and superordinate and

subordinate such concepts: “chair” is base level; “furniture” is superordinate; “armchair” is subordinate.

Egocentrism: This term at first sight covers a much wider range of phenomena than our comparatively mild notion of the “egocentric” mode of cognition. We see in chapter 9 how they’re identical if we re-interpret autistic mentation to include also Piaget’s notion of the egocentric. In Piaget, it referred to a tendency to take one’s own view of things as the only possible view. As such, it should sound depressingly familiar. However, it also could express itself in adolescent messianism, the tendency of the recently pubertal to convert us all to their views now that they could themselves think. It has been misrepresented as wilful ignorance (Sugarman, 1988). What Piaget wished to point out was rather a state in which children failed to differentiate themselves from the external world. Sugarman’s critique of Piaget is so pointed, and so explicitly directed at his notion of egocentrism, that we shall take some time to examine it.

There has been a great deal of experimentation on egocentrism. Children of 19 months will carefully turn an object around so you have precisely the same view of it as them. However, Piaget’s experiments showing children as old as eight making similar perceptual errors have been exposed as badly designed. This is not the main plank of Sugarman’s accusations. Piaget, she argues, is in turn charging infants with egocentrism. In order to justify this charge, he must establish that the children have what amounts to full adult competence in the area in question, but for some reason choose not to use it. However, this is not Piaget’s position, nor those of his fellow-travelers like Polanyi (1958) whose conception of the child is also that of a body-subject which sees herself as fused to an environment.

It cannot be too strongly stressed that what both Piaget and Polanyi are talking about is an infantile sense of lack of differentiation from the external world (see also Nolan, 1990), rather than some kind of perverse deliberate placing of oneself at the center of the universe. Merleau-Ponty considering his arm as an object (diagrams 1.2 and 1.3) is a differentiated act of consciousness; considering it as a subject is, in the Piagetian sense, egocentric. This point gains in importance because on it hinges a great deal of the main thrust of Sugarman’s argument that there is no theory of mind in Piaget. On the contrary: not only is there a theory of mind, but also an elaborate theory of the development of mind. The later logicist excesses we duly castigate in 2.4.3.4. However, Piaget’s starting-point, that of a body-subject gradually and simultaneously getting to know about the world and his role in it, is the best possible starting-point for a theory of cognition. It is compatible with the mundane world of Merleau-Ponty and its notion of development through a lifeworld (Lebenswelt), with the biological basis which CS ultimately needs, and with the theory of consciousness as progressively developing rather than as a given which we plumb for in chapter 8.

Let’s now try and tie many of these strands together in an account of Piaget’s stages of development. We’re going to quote a little from Piaget as we go to get an insight into his style of reasoning.

B Piaget's account of development

For Piaget, reality is by no means a constant array of unchanging objects. He explicitly denies the thesis that 'there are objects existing as such for the subject'. Instead he insists that knowledge arises from interactions that take place midway between the two (i.e. subject and object). His system can be viewed as an extraordinary analysis of the development of knowledge, using this single theme as key: "I only know an object to the extent I act on it."

We are then to examine Piaget's system as a "psychogenesis of knowledge starting from the original indifferentiations." The first of these indifferentiations is between self and world. Piaget posits the infant's lack of true selfhood. "The young infant relates everything to his body as if it were the center of the world." Yet there is no self-awareness at this point. The situation has been described both by Polanyi (1958) and Piaget as "narcissism without Narcissus." Only with the beginning of "coordination of actions' does self begin to differentiate itself from world.

Piaget labels the stage of development described above as the "Sensorimotor stage." He addresses himself explicitly to the question as to how the adult world of well-established subject and objects develop from these beginnings. During the second pre-operational phase, logic begins to be foreshadowed in "internal co-ordinations of the subject' and causal relations are similarly represented by "external co-ordinations between objects." However, there is not as yet any fixed independent external world.

We must interrupt our account at this point to consider the evidence Piaget has collected to support such remarkable claims. His experimental methodology is self-consciously informal and makes use of verbal protocols "the surest method… is to analyze the proofs employed by the subject" (Piaget, 1958). These proofs often seem to involve failure by the subject to distinguish between his own actions and the objective workings of the apparatus. "[At the preoperational stage] the subject is most likely to explain the situation in terms of the totality of actions he can perform on the apparatus" (Piaget, 1958). The state of affairs at this point is summarized by the statement "the subject's physical actions still entirely dominate his mental workings." As yet, there is no mode of representing reality independently of possible actions upon it.

We have already encountered one of the core-concepts of Piaget's system i.e. his insistence that representation takes different forms at different developmental stages. At the next stage that of concrete operations, representation is mediated through reversible transformations instead of conceptualized actions. The emergent competence corresponds on the temporal dimension to "the fusion into a single act of anticipations and retrospections" (Piaget, 1970). The emergent objective relationships allow new ability "to order… serially" and "observe frequencies objectively" (Piaget, 1958). The more veridical view of reality obtained emanates directly from a differentiation of subject from object.

In a further development, from the stage of concrete operations onwards, subjects tend to describe stimulus situations in terms of possible transformations that can be performed on them rather than in terms of their perceptual configuration. "… every

state is conceived of as the result of a transformation." The actual converges with the possible in an encompassing representational act.

However, as yet form has not been separated from content. The reversible system of operations which defines the concrete operational stage is not completely content-independent. The acts of seriation, equalization, and so on. cannot be performed with equal competence on all materials or in a manner which disregards the subject's mode of representation of the material in question. Piaget points out that the critical difference obtained between types of materials which are earlier part of the subject's concrete operational competence and other materials stems from the fact that the latter category feature properties which "… less easy to dissociate from one's own actions." Mass is understood later than length because of their relative susceptibilities for objectification.

Only at the adult "formal operational" level of thinking is there established an enduring differentiation between subject and object. Similarly, the symbolic mode of reasoning heralded by the onset of formal operations finally sets form apart from content. "Formal thought no longer deals with objects directly but with verbal elements." Experience is vastly broadened by the mental operations afforded. "It is now reality that is secondary to possibility" (Piaget, 1958).

We have come close to the final point of Piaget's account of development, a point at which the complementary processes of interiorization and exteriorization have produced a system of mental operations "… which at last frees itself from physical action and the universe." (Piaget allows for a later stage at which axiomatic systems like Euclid's may be developed). Only now can those actions Piaget stresses mediating subject and object which constituted the touchstone of our analysis be disregarded.

It should be obvious that a stimulus situation which presents a problem at one level of development may not do so at another. One of the classical experiments in the Piagetian framework asks subjects at various stages of development to supply an explanation for the equality of angles of incidence and reflection. Every pool player knows that, in the absence of side-spin, these two are equal. At the preoperational stage, the only issue is that of "practical success or failure" (of the experimental manipulation): the central problem cannot even be conceptualized. Subjects at the level of concrete operations fail to arrive at a general law, which is only achieved at the stage of the formal operations.

The following section concerns Piaget's logicism. It can safely be avoided by those averse to logic; others may find it the most interesting part of Piaget's system. A line of asterisks welcomes the non-logicians back.

C Piaget's Logicism

It was stated above that, had Piaget wholly succeeded in his goal of tracing cognitive development all the way from biological interaction to logic, there would be nothing left for Cognitive Scientists to do. Note that it is not being suggested that he totally failed; what is being argued is that the questions he asks about knowledge as a biologist, philosopher and psychologist are the correct ones, and that many of his

concepts like assimilation/accommodation, transformations, stages of representation, operational knowledge and internalization of actions are similarly appropriate.

However, he stretched himself a little too far. His eventual aim was to explain logic in action using the same set of concepts as for biological adaptation and psychological processes. Above all, he insisted that Kantian categories like logic and arithmetic had to emerge naturally and in a principled way from natural adaptive process. His style of reasoning led him to describe many processes in logical terms that may be better described otherwise (see below for the discussion on symmetry). Specifically, he often attempted descriptions in a fully-fledged and intricate logical formalism for processes which are much better described in other terms.

For example, he attempted to describe concrete operations in terms of "elementary groupings," which lacked the power of full propositional logic. He continued in his further speculation, to describe pre-operational thinking in terms of a "semi-lattice" with no capacity of set intersection. If all this leaves you at the starting-post, don't worry. It's there simply to reveal the labyrinthine world of Piagetian logic. Instead of the kind of axiomatic system we describe for production systems (see below on problem-solving), Piaget described his logic as an "operational algebra."

His symbolism obviously demands explanation. He generally expresses binary logical operations as equations. The right-hand-side of the equivalence sign represents the possible truth-values of the two propositions under consideration. In any particular case, only certain combinations of truth-values are valid. The left-hand-side features the conclusion to be drawn. It must be pointed out that, regardless of the equivalence sign, these statements are not equations. This point will become clear after we consider the example below. We're going to need logic for the rest of this book, so let's get used to it. & means and, v means or, i.e. (thunderstorms & rain) means we can't have one without the other: (thunderstorms v sunshine) means that there is incompatibility there.

Piaget claims all adults possess a degree of logical competence which seems at first glance truly extraordinary. Adult logical competence has four components:

1. Actual situations can be represented accurately in their absence. This component follows necessarily from the fact that stimulus situations can be represented in propositional terms.
   "Reality is secondary to possibility… propositional thinking is essentially hypothetico-deductive" (Piaget, 1958).
2. Let, p, q, r and s signify, respectively, three independent and one dependent variables. Subjects are informed that p is the result of a particular combination of q, r and s. For example, the color yellow (p) might result from the addition of 3 chemicals (q, r, s). Piaget claims all adults can apply combinatorial reasoning to discover what precisely is the required combinations or "generate a combinatorial system which corresponds to the observed facts" (Piaget, 1958).

   This logical operation is symbolized $(p\&q\&r\&\bar{s})$ v $(p\&q\&\bar{r}\&\bar{s})$ v $(p\&\bar{q}\&\bar{r}\&\bar{s})$ v $(p\&\bar{q}\&r\&\bar{s})$ v $(p\&\bar{q}\&\bar{r}\&\bar{s})$ v $(p\&\bar{q}\&\bar{r}\&s)$ v $(p\&q\&r\&s)$. Subjects "form their judgements according to a combinatorial system and so this logical operation, Piaget argues, corresponds precisely to what's going on in subject's minds.

3. The repertoire of logical operations attributed to adults includes a set of 16 binary operations.

   'We are not exaggerating when we claim that it is possible for subjects at this level to work in turn with each of the 16 binary operations of standard logic' (Piaget, 1958).

   As we have already seen, these operations are founded on two operations and the standard logical connectives.

   At this point it is appropriate to illustrate by example. In one of Piaget's rather better-known experiments, Ss are requested which variables determine the period of oscillation of a pendulum. The possible critical variables are weight (w), length of string (l), impetus (i). Let q signify the periods increasing, q the periods decreasing.

   We first of all examine the binary operation implication.

   $(l = q) = (l \,\&\, q) \vee (\bar{l} \,\&\, \bar{q})$

   It will be remembered that the right-hand-side of the equation features the possible truth-values of the propositions under consideration. In the same manner as q and $\bar{q}$; l and $\bar{l}$ (likewise w and $\bar{w}$) signifies increase and decrease in the relevant dimension. It should be obvious that there are two possibilities i.e. that the length and period should together increase, and that they should likewise simultaneously decrease. Consequently, a relation of implication holds between length of string and period of oscillation.

   The binary operation "tautology" establishes that the weight of bob is independent of the period of oscillation $(w \circ q) = (w\&\bar{q}) \vee (\bar{w}\&q) \vee (\bar{w}\&\bar{q}) \vee (w\&q)$. The binary operation "disjunction" establishes that either the weight of the bob or the length of string is critical. $(w\&\bar{l}) = (\bar{w}\&l) \vee (\bar{w}\&\bar{l}) \vee (w\&l)$.

4. Piaget time and again insists "one may find the roots of logical and mathematical structures in the coordination of actions" (Piaget, 1970). Thus, perhaps his proposal that a group of transformations isomorphic to the Klein four-group forms part of the adult logical repertoire. I. N. R. and C stand, respectively for identity, negation, reciprocity and correlativity. This INRC group can operate both on combinations of two propositions and within itself. It goes without saying that the INRC group has a psychological referent:

   'We should not be astonished if we find this same INRC structure in the very reasoning of the child" (Piaget, 1958).

   It is generally agreed that this "Vierergruppe" is an unnecessary appendage to the Piagetian system. It will suffice to take stock of the operations I and N :

   I (pvq) = (pvq)
   N (pvq) = (p&q)

   Likewise, the defining intragroup operations may be specified thus:

   NI = N
   CR = N
   INR = C
   CRN = I

   In a further elaborate schematization, Piaget brings the INRC group to bear on the notion of logical proportions.

How much evidence is there for being able to attribute all this logical competence to the average adult? Extremely little, as it turns out. Moreover, his formulation is unwieldy in the extreme: we're gong to note that the Gestalt tradition would solve the pendulum/bob problem hinted at above by invoking the elementary notion of symmetry. Finally, we'll see that most adults find it extremely difficult to reason with propositions in the manner just outlined. They can, however, perform tasks which are logically precisely identical if more content is supplied. Let's take the logical form, "Modus Tollens," as an example.

1. If p then q
2. Not q
3. Therefore not p

Dreadful isn't it? However, look at this:

> If the check is valid, it's signed at the back.
> The check is not signed at the back.
> Therefore…?

Yes, that makes it a lot easier!

Logic seems useful in the psychology of reasoning as a descriptive tool, rather than as a prescription of what's going on. It also serves a purpose as a model of the competence of the ideal human logician, as distinct from her performance (see chapter 3 on this distinction in linguistics). Piaget's logicism is probably the weakest part of his system. Had he demonstrated logic's fundamental role in reasoning as he attempted to do, all the problems of formalization of mental process would have been solved for AI as much as Cognitive Psychology.

D Piaget and Mylesianism

Before discussing Piaget's relationship to the framework here, let's note his relationship to his philosophical antecedents and contemporaries. As a philosopher, he can be read as attempting to give a developmental account of Kantian categories as necessarily arising from the inevitable facts of our interaction with the world.

Nor is his framework in any way incompatible with Merleau-Ponty. We can view Merleau-Ponty's phenomenology of perception as the experiential dimension of the biologically-based interactions which Piaget sees the organism as immersed in with its environment.

Merleau-Ponty wrote much on Piaget without really coming to grips with where Piaget can fill up the gaps in his own work. We noted that Merleau-Ponty has difficulties with explaining how symbols can arise from perceptual experience, a failing he shares with Brooks (chapter 5). Piaget insists that symbols can arise from the internalization of actions. (In fact, he takes this argument a little too far in the case of language. I find his account of mathematical reasoning as internalization of action convincing, but we're going to see in chapter 4 that he can't as easily explain language development). It is difficult to access location where Piaget can best inform Merleau-Ponty.

Merleau-Ponty places the subject in an intersubjective world and fails to note that there are many situations where we make sharp distinctions between ourselves and the conceived external world of people and objects. Piaget describes how this separation can occur. Yes, the child's world is Narcissism without Narcissus, fusion with an encompassing environment. However, we noted in the glossary entry on centration that subject-object differentiation can actually occur. Remember Archimedes rushing from the baths in chapter 1! Cognitive development in the Piagetian and Mylesian frameworks features a myriad such events.

In fact, the intersubjective domain is characterized mainly by such events which all of us experience. Yet what is intersubjective for one group may not be for another: a group of musicians may agree precisely on the superiority of Mozart over Salieri in a way which is caviar to the masses (at least those who have not watched *Amadeus*!).

Moreover, with Piaget's notion of operational knowledge, we can give the first hint of the meta-framework of this book ("the Nolanian system" is actually a phrase coined by John Flavell in a conversation at Stanford the day before Thanksgiving, 1983). It will be argued in chapter 3 that the standard linguistics account of language must be supplemented by an account of this operational knowledge, and how it interacts with the formal system of language in idiosyncratic ways in particular contexts.

E Conclusion

Many of Piaget's concepts are still heuristically useful. First of all, his questions about knowledge as a biologist, philosopher and psychologist are still extremely pertinent and cognitive science cannot properly proceed without confronting them. Secondly, we shall use the following Piagetian notions: schemes and schemata, equilibration, conservation re-interpreted as an advance in self-awareness, operational knowledge, autoregulation of knowledge structures in interaction with an environment, different types of representation, decentration with an emphasis on subject/object differentiation. I am fully aware of the lacunae in Piaget's experimental work: he also makes the same mistake as CS of ignoring affect and social factors. Given the tremendous scope and power of his project, it is not surprising that the great majority of his critics have, implicitly at least, adopted some or all of his framework (Donaldson, 1978). Perhaps that is the ultimate tribute.

2.4.2.4 Behaviourism and Learning

Some important aspects of learning can usefully be described using only the concepts of behaviourist psychology. The problems with this approach arise when it adopts a "nothing but" approach i.e. when no significant causal role is attributed to mental structures.

Our discussion of Gestalt psychology above featured an interlude where we spoke about generalization. For example, a stimulus may be responded to in the same way even though the frequency varies over a large band of the auditory spectrum. The other conceptual tools of behaviourism are reinforcement schedules, which can involve only occasional (interval) rewards (the most cost-effective), continuous or negative reinforcement in behavioural therapy. However, behaviourism ends in absurdity when

trying to give a thoroughgoing externalist, stimulus-response account of behaviour which involves use of systems (arithmetic, language) by the organism. (Indeed, Skinnerian behaviourism, unlike Hullian, has difficulties with learning involving any internal processing). Besides this, we need an elaborate version of feedback, by which the organism can adapt its actions, even for simple behaviour.

2.4.2.5 The development of innate symbolic systems and the language of thought

Language development famously does not admit of a parsimonious description in terms of behaviourist psychology (see chapter 4). In fact, the death-knell for behaviourism's domination of American Psychology began with Noam Chomsky's review of Skinner's *Verbal Behaviour*. In retrospect, it seems likely that Chomsky was motivated politically as much as academically. Skinner had outlived his blueprint for an ideal state in the fictional *Walden*, which featured precisely the type of state control over people's lives (by "enlightened" use of behavioural psychology) which Chomsky is known to loathe and fear. Whatever the truth about that, the cognitive revolution in psychology finished off behaviourism's pre-eminence.

It seems a safe verdict that language develops to some extent autonomously, and this happens as the consequence of the unfolding of an innate capacity. Moreover, it seems valid to say that all human languages fall within a certain narrow range of formal complexity (again, see chapter 3). What I shall show in chapter 7 is that the same situation seems to hold for the symbolic system of music, and may indeed hold for vision where the nature of the symbols is less clear.

In that chapter, a contrast is emphasized, for any cognitive act involving symbols, between the characteristics of the formal system involved (language, music), the operational knowledge implicit in the act and the subject/object (ontological) relationship therein (see figure 3.4). What is important about this schema for the moment is that we cannot explain cognitive development as the development of any single symbolic system, whatever its power. We shall note in language development a great deal of evidence concerning the role of operational knowledge. Yet this in no way diminishes the importance of understanding the formal rules (the grammar) underlying our comprehension and production of language.

I fully realize the word "ontological" is being used in a sense other than the classic philosophical one of chapter 1 or the knowledge engineering sense in AI, where the ontology of a system lists the types of entities used therein to map the domain it addresses. Laing (1969) uses "ontological" in precisely the "conceiving oneself as object " sense we need here. His concerns, which will briefly border ours in chapter 8, is to explain mental illness in phenomenological terms above all as alienation from self. It is not my intention to claim any direct link between linguistics and psychopathology.

In 2.3 we discussed Fodor's (1983) "modularity" hypothesis. No discussion of innatism would be adequate without reference to his (1975) notion of cognitive development as the unfolding of a "language of thought." It behooves us also to clarify exactly what Fodor is attempting. We have cited him in 1.4.5 as an antagonist of CS, which is in at least a limited sense unfair, and need to get firmer purchase on what he

is saying to understand where this notion of a language of thought fits in his work. In fact, he is not a priori an opponent of CS. His hostility is directed solely at its more ambitious project of characterizing *everything* about the mind. In fact, Fodor has little or no difficulty with the notion that the projects of CS and of the philosophy of mind should overlap; he is skeptical, however, about the prospects of CS ever formalizing anything other than the basically syntactic operations performed by vertical modules. The horizontal modules which comprise the intentional system are of a different nature, and beyond our purview.

One of Fodor's starting positions, that of methodological solipsism, is classical CS: computation over representations comprises cognition, and therefore there must be a language of thought in which representations are couched for cognition to occur. This language of thought is innate, i.e. from birth we already possess the complete set of representations, and the world with its apparently "busy and boundless fancy"is actually just painting these representations by numbers. Learning is impossible. The type of logical law exemplified by Modus Ponens in 2.4.3.2 cannot be extended to other more nuanced cases, as discussed in that section.

Innatism, like absolute idealism, is more or less irrefutable. So you once had concept X and now you've got concept Y. But Y is logically distinct from X! You can't possibly have learned it as an extension of X! However, there are at least two major caveats here: one is that different types of representation of a problem can have huge effects on its solvability (2.4.3.2 has a demonstration of this); secondly, and returning to 1.1.1, how is it that only Archimedes of his contemporaries discovered specific gravity? Remember that Lonergan's account of insight insists that it is a function both of internal and external factors. We must allow the environment in somehow. We can explain this particular phenomenon by insisting that Archimedes had simply unearthed the applicability of innate concepts like equality in a new context. The result, however, is a new concept which passes into the habitual structure of the mind. The notion of an innate language of thought, then, like that of modularity itself, risks trivialization. It might reduce to a very limited set of context-independent operations (like Modus Ponens) applicable to thought in every conceivable context. Finally, just as we concluded above with Jackendoff (1987) that there must exist a variety of "horizontal modules," so can we also insist on languages of thought applicable to personal and athletic skills as to the purely intellectual ones which are Fodor's focus.

2.4.2.6 Summary

We have received a vast range of learning mechanisms, from agglutination of connections between stimuli and responses to growth of systems like language and logic. All of these are important, but the use of structured knowledge like logical systems gives an extra dimension of power. Let's now look at how these systems can be used in problem-solving.

2.4.3 Memory and Problem-solving

To what extent is memory involved in problem-solving? Or do we often create new solutions to problems, be they crossword puzzles, satisfying our sexual needs or

getting ahead in our careers? We begin this section by looking at Max Wertheimer's (1959) approach to these issues. We find that he distinguishes between different types of problem-situation and different types of solution process. For a large subset of problems, the surprising thing is that solution depends on a precise specification of the problem! For others, like artistic creation, the situation is different.

We discuss the "neat" problems first and note deduction as a type of solution mechanism. We then go to the opposite extreme and ask whether sometimes we aren't just making statistical guesses about solutions. Finally, we discuss neat types of solution which are yet not dependent on deduction. These types sometimes involve subject/object differentiation like that of Archimedes.

2.4.3.1 Types of problem and types of solution

Wertheimer's (1959) is the most sophisticated account within psychology of the process of problem-solving. Let S_1 represent the situation in which the actual thought process starts and S_2 the end of the process. Wertheimer stresses that solution and problem are part of a single coordination. "The thesis is that the very structural features in S_1… lead to the operations dynamically in line with the essential requirements' (Wertheimer, 1959). He points out three different types of problem. The first is represented S_1… S_2 (or… S_1… S_2… if one insists on looking at the problem in the context of the individual's life-space). This closely resembles crossword puzzles – other "convergent" thinking; the second type, represented S_1… resembles open-system, "divergent" thinking or scientific discovery. The achievement here is the realization that a problem actually exists "that the situation is not in such good order" (Wertheimer, 1959). Finally comes the type of discovery characteristic of art rather than science. The artist begins by envisaging some features in an S_2 that is to be created.

The central issue in Wertheimer's work is the distinction between "fine, clear, A-type" solutions and "blind, fortuitous, B-solutions." The former type involves a restructuring of the problem according to the Gestalt Prägnanz laws. "A new, a deeper structural view of the situation develops involving changes of the functional meaning of the items." In this process of reconstruction, the role of individual items is changed according to their role in the new structure. Think of how two letters in a word look before and after you have solved a crossword clue.

Wertheimer's demonstrations are mainly mathematical, rather than scientific, in nature. Solution is normally effected by the perception of "rho-relations" between aspects of the stimulus ensemble. The accounts he gives of scientific discoveries involve more sophisticated rearrangements. Moreover, scientific discovery involves a preparatory period during which an ill-defined sense of incompleteness of a research area resolves itself into concentration on a particular region. (These two types of account correspond respectively to S_1… S_2 and S_1… in the schematization above.)

An example of an A-type solution procedures is the process by which children derive the formula for the area of a rectangle from that of the area of a square. For Wertheimer the derivation emerges from a consideration of "how parts fit together and complete the area… a realization of the inner relatedness between their fitting together and whole features of the figure" (Wertheimer, 1959). A^2 is the area of a square, where

A is the length of any side. Let L and B respectively represent the length and breadth of any rectangle. According to Wertheimer, solution proceeds from the restructuring of the rectangle into L _ B squares of unit area.

We've seen Gestalt psychology stress the role of whole-qualities in perception. Wertheimer gives a detailed account of the role of whole-qualities in problem-solving. Symmetry is one such whole-quality not reducible to a "relation of relations." Wertheimer uses a purely mathematical example to illustrate the role of symmetry. The sum of a series 1… n can be 1… obtained by multiplying the sum of the extremities (n + 1) by the number of pairs (n divided by 2 for even numbers). Only by grasping "the necessary symmetry of the series" and then becoming aware "of the inner (rho-) relation between form and task" can the formula be understood. The symmetric form in question emerges from the realization that each pair in a restructuring of the stimulus material adds to n + 1. There are (n divided by 2) such pairs for even numbers. The two quantities are *reversed*?? in the case of odd numbers but the role of symmetry is the same.

The nature of restructuring should now be clear. Restructuring plays a considerable role in scientific discovery but must be preceded by focusing upon a certain region in the field under investigation. Galileo's discovery of inertia stemmed directly from a dissatisfaction with the contemporaneous accounts of acceleration. Having experimented with the change of quantational acceleration with increase in slope of a plane down which an object rolled he began to consider the complementary concept of quantational deceleration. The two pictures together furnished an inchoate situation with the whole-quality of symmetry. Galileo's discovery of inertia corresponds to the schematization… S_2 we used above to describe artistic creation. However, the main achievement was, as Wertheimer puts it, "to get a clear, clean structural insight against the sophisticated background." Galileo's main achievement lay in actually defining the problem.

The procedure of restructuring the problem as a *sine qua non* of solution will be re-examined in detail in a later chapter. For the moment, however, "centering is the most relevant to us of the procedures. Wertheimer describes "centering" as defined as "the way one views the parts, the items in a situation… with regard to a center, a core" (Wertheimer, 1959). It refers particularly to the process of conceptualizing one's needs as part of a situation rather than as the meaning of the entire situation. Such a transition between viewpoints "may lie in the deeper requirements of the I itself" (Wertheimer, 1959.) At this point we are near one of the main themes of this book.

For Wertheimer, conceptual confusion is often the direct result of miscentering. He points out, moreover, that "the problems of centering are ignored in traditional logic and psychology."

Centering can be a restructuring of the stimulus ensemble. What of the process of viewing one's desires as part of an encompassing situation? There is one passage from Wertheimer (1959) worth quoting at length at this point:

"The role of the merely subjective interests of the self is, I think, much overestimated in human actions. Real thinkers forget about themselves in thinking. The main vectors in genuine thought often do not refer to the I with its personal interests."

Moreover,

"… problems often remain insoluble so long as one focuses on one's wish or need…."

The sympathy with Piaget's description of cognitive development as progressive objectification of the external world is obvious. This process of differentiation between subject and object is not formalizable in logical terms, as Wertheimer (1959) points out. It will be re-introduced in chapter 8.

We have now considered the variety of processes which Wertheimer cites as contributory to the creation of novelty. What of his viewpoint on the question whether problem and solution are in fact complementary, in the sense outlined above. He is explicit on this point:

'S1 contains structural strains and stresses that are resolved in S_2. The thesis is that the very character of the steps, of the changes, of the operations between S_1 and S_2 springs from the nature of the vectors set up in these structural troubles…."

In other words, unresolved tensions within the problem (S_1) already imply the steps required for solution (S_2).

2.4.3.2 Problem-solving as deduction

It would, of course, simplify matters greatly if we could regard all problem-solving behaviour simply as logical deduction. We have spent a long time (rightly, as it turns out) agonizing about problem-definition and problem-solution. Let's go to Disneyland (or EuroDisney) for a moment and imagine that in this fantasyland all reasoning proceeds like this, using the logical terminology we have already introduced:

> If p then q
> p
> Therefore, q (Modus Ponens)

We construct systems which comprise structured sets of such rules:

> If the Jets play the Sharks, the Jets win
> They're playing
> The Jets are going to win

with similar rules about the Dolphins, Cod and Mackerel etc. Eventually, it becomes a trivial matter to decide who is going to beat whom. We need just refer to our table to figure out exactly what's going to happen. We call such a table, combined with its principles of operation, a production system.

Fodor's argument on innatism, in the context of production systems, essentially boils down to this: let us say that the child has "learned" Modus Ponens. Now consider this as the second premise: The Jets have just lost. The conclusion, from another reasoning schema called Modus Tollens, is that the Jets did not play the Sharks. However, let's rephrase the opening premise as "It cannot happen that the Jets and Sharks play, and the Jets lose." By changing the representation, we have catered for

both schemata. This could well be the way that the situation is represented in the language of thought. If, however, we extend the situation by introducing qualifiers like "sometimes," Fodor would argue that we are on different ground, and need new innate schemata to explain how the reasoning form is "learned."

In our Disneyscape, a serpent may occasionally enter the garden. It asks: Does the brain really process propositionally in this matter, or does it construct mental models mapping this knowledge? This serpent's importunate query can take up volumes of Cognitive Science journals (the Johnson-Laird vs Rips saga, see Rips, 1990).

We can alternatively simply note that propositional logic systems, as outlined, seem on the balance of evidence to have some psychological reality. Whether they're actually implemented as spatial mental models, or solely as intricate systems of propositions, we can assent to their causative functions. Sensible people, we remain with this point of view pending further evidence on exactly what types of codes the brain is capable of.

2.4.3.3 Probabilistic Reasoning

Given what we know about the brain, we shan't be surprised if through our fairly complete ignorance a ray of light concerning the adaptive nature of thought occasionally shines through. Neurons can have hundreds of thousands of connections with each other (see chapter 4). It seems extremely unlikely that the neural "language of thought" is an all-or-none affair: rather, aside from the possibility of different levels of code, thought should work probabilistically. We should constantly guess at what's going to happen next in order to function effectively in the world.

Let's recall Sperling's work (section 2.2). A first "guess" at the proper interpretation of a stimulus array is the entire array. This gradually gets further and further focused until we come up with the interpretation we need. Consider language-processing (see chapters 3 and 7). Evidence suggests that immediately on hearing an ambiguous word like "bank," we activate all its meanings. Our current context of action results in just one of these being chosen. This choice is a probabilistic process. We can conceive of much everyday living as problem-solving, particularly if we allow for probabilistic reasoning. In chapter 5 we look at the Bayesian approach. For the moment, let's note that neurons' connections seem admirably suited to implement probabilistic processes: moreover, the facts of the activities of all sensory/symbolic modalities (language, vision, and so on) seem to confirm its importance.

2.4.3.4 "Fine" solutions

We've had a taste of Wertheimer and know what he means by A-type solutions. What we must do now is spell out the consequences in terms of subject/object relations.

For Wertheimer, fine solutions are given by "rho-relations" between subject and object. Once more, what precisely are rho-relations? Wertheimer speaks of "… the kind of inner relatedness which is outstandingly reasonable because of the rho-relation, the fitting together of requirement and result" (1959). However, they are easier to recognize than to define. We noted several of them above.

Let's return to symmetry. Piaget claims that formal operational thinking is prerogative for solution of a problem involving symmetry: "The idea of an equivalent amount of work half-understood during stage III (formal operations – italics added)$$$, provides the explanation of the phenomenon of equilibrium" (Piaget, 1958). For Piaget then, understanding of equilibrium is not achieved until adulthood. Wertheimer denies that and adduces empirical evidence to support his viewpoint.

The Piagetian system here must be faulted for a certain inelegance. It is forced to posit an inordinate amount of sophisticated logical operation in explaining, for example, how a child comes to equilibrate the sides of a balance. Let p and q represent respectively, increase in weight and in distance from the midpoint: p and q represent the respective decreases. The same propositions must be asterisked to describe the corresponding factors on the other side of the balance. Operations from the INRC group are required to implement the equilibrating process: I (p. q) = to increase simultaneously weight and distance on one side. This is not by any means the whole story: the major lesson is how cumbersome Piaget gets on these matters.

For Wertheimer, on the other hand symmetry is "an outstanding whole quality… in turn an outstanding inner relation with the stability of the whole – a rho-relation." He points out that symmetry is a universal element in preoperational children's conceptual structures and so cannot require any system as complex as the INRC group. An experimental situation closely resembling Piaget's found in many children "… very soon a considerable tendency to focus on the middle" (Wertheimer, 1959). Wertheimer extends his argument to scientific discovery, remarking "… structural symmetry in dynamics played a significant, important role in Galileo's thought processes and in modern physics."

Such pronouncements are outside our range of interest here. Nevertheless, there can be no question but that the notion of rho-relation affords a more parsimonious description of adult reasoning on problems involving symmetry. Piaget's system cannot explain the competence young children showed on Wertheimer's symmetry problem.

Another type of fine solution involves the introduction of a new concept: we have seen that Galileo added deceleration to what was already postulated about acceleration and managed to square that particular circle. Yet this new concept has a symmetric relation to the old one! Perhaps Mind in Nature also invented symmetry at some stage (as you read this page hopefully with both eyes open).

2.4.3.5 Why solve problems, anyway?

Or rather, why create them for oneself? What precisely is that factor within us which forces us out in the world, often into unprecedented and unpleasant situations, going to trouble to make trouble? We discuss this in chapter 8.

If our conceptual structures are incomplete then so is the Universe itself. The paradoxical search for novelty against a background of stability seems to be common to all human beings.

A science of cognition which ignores affect, conation (the will) and social factors can explain how problems are solved, once they have been defined. However, it is clear to

us now that this is only the beginning. We need to know, for any given person, what they are likely to perceive as a problem in order to predict anything significant about their future behaviour. We would like to know something about the problem-solving style they are likely to adopt. Finally, we might find that some people are more driven to seek out and solve problems than others. In fact, it might be said that our exclusion of affect, conation and social factors has robbed our science of much of its significance and explanatory vocabulary. In short, it now lacks ecological validity.

There are several different accounts (with wildly varying degrees of subtlety) of motivation in psychology. It is the practice of this book in such cases always to take on board the most encompassing viewpoint, the perspective from which all other views can be seen as special cases. Abraham Maslow's work affords such a perspective. It posits a hierarchy of needs, starting from the biological ones of air, water, food and sex. Only when the earlier ones on the list have been fulfilled can one focus on fulfilling the next. Maslow suggests that the next set of needs relate to expansion of one's competence on some way, i.e. self actualization. This competence can be a matter of understanding more as well as being able to do more. It may in fact relate ultimately to knowing precisely what ones real nature is. For example, the desire to achieve competence at a musical instrument is also the desire to know what one's expression of one's self will be in the world opened up by this new expertise. We return to this in chapter 8. For the moment, let's ask ourselves why Archimedes was at all attentive to the external effects due to his body's immersion?

That type of phenomenon we can treat with an extension to the vocabulary and concepts of Cognitive Science which allows a causal role to subject-object differentiation. Let's end this subsection by noting that what people live for has a profoundly causal role on their cognition. This raison d'être has so far been better handled by the structures of myth and religion than affect-free reason.

2.4.4 Memory and Forgetting

First of all, let's focus on easily quantifiable types of forgetting. If, in the manner of the late nineteenth century psychologist Ebbinghaus, we learn one list of nonsense syllables and shortly afterwards learn another, they interfere with the recall of each other (proactive and retroactive interference, as we go forward in time). All such interference is catered for by a construct known as the "fan effect."

Another type of forgetting is the myriad data items we ignore in our perceptions from moment to moment. We've noted that the self/not self distinction is extremely important in the preservation of a coherent information flow. In this context, let's briefly refer to the puzzling phenomenon of clinical autism. Child prodigies exist who can play extraordinarily complex music by ear, draw extremely detailed cityscapes or, in the manner of Raymond in *Rain Man*, instantaneously count a heap of spilled matches. Yet they cannot function normally socially. RAM assigned to social processes in normal humans has become dedicated to symbolic activity of some sort. Is the genius of Mozart therefore essentially his capacity to maintain a foot in both worlds? The recent bestsellers *Nobody Nowhere* and *Somebody Somewhere* (Williams, 1993) are written by a sufferer of clinical autism. The single most remarkable aspect of her

accounts is precisely the different conception of the relation between subject and object to that "normal" people are accustomed. This is exactly as the stance on the relation between consciousness and self taken in this book would predict.

We've noted that Freud's theory allows suppression of painful memories. However, this "repression" is just the tip of the iceberg. "Psychogenic Fugue" is the phenomenon whereby one forgets all details of one's social being. Multiple personalities (often the possession of a subject who was physically abused in childhood) may or may not know of each other. These kinds of phenomena sit more easily with a fully worked-out, ecologically valid psychology than millions of experiments churned out about memorizing single sentences (We revisit this theme in chapter 8.) We find ourselves asking questions like:

- To what extent are we solely the result of our experiences?
- Can social selfhood actually be abstracted from the subject's total experience of the world?
- What are genuine human similarities and differences?
- Which experiences are central, and which are peripheral, to consciousness?

2.5 Mind in Psychology

We have briefly analyzed many of the huge variety of approaches to Mind which form psychology, including those which reject the usefulness of the concept of mind. We remain with our definition of mind as manifest in the organism's interaction with its environment. En route, however, we have become aware of data about behavioural conditioning, the cognitive function of self, the metaphysics of subject/object relations and the abysses revealed by depth psychology which give us pause before coming to any too easy conclusions. Moreover, it has become obvious that we need to complement the notion of mind as immanent with an articulated theory of symbolic functioning. In other words, we cannot treat all mentation as simply the picking-up of affordances.

The starting-point for our theory of human cognition is that of the human organism immersed and embodied in a Life-world. A prior intuition of the existence of an external world, including the intersubjective domain and three-dimensional space, is assumed in the manner we saw Merleau-Ponty demonstrate in 1.3.2. To understand cognition we must understand its development. To understand its development is also to plot the growth of consciousness through successive differentiations and integrations.

This chapter began with a statement of the central problem of psychology: the mapping of significant areas of human experience in a scientifically valid manner. We then proceeded with a history of experimental psychology, referring also to depth psychology and phenomenological psychology, before discussing the types of methodology which time has proven valid. This analysis is then related to the Nolanian framework: we find that its prominent accent on consciousness makes phenomenological psychology a valid medium for the delineation of experience. We went on to discuss the relation between perception and cognition and found that allowing perception the role of the background for acts of cognition means that a given

act of mind may change from being included under the rubrics of the latter to that of the former.

Human cognition cannot possibly properly be discussed except with respect to its development. We used the concept of memory to elucidate aspects of learning, problem-solving, information-processing and forgetting. Piaget's is still the most comprehensive theory of cognitive development. Its many shortcomings can be justifiably attributed to the sheer scale of what he attempted. In fact, its concern with philosophical epistemology, its emphasis on situated cognition and its biological reference are making it look surprisingly modern. Paradoxically for CS, its major fault, the logicist obsession, gives it a computational accent. We discussed Piaget's work critically before salvaging those concepts like operational knowledge which, together with the very questions he asks, are the most valid notions in Piaget.

Our analysis of problem-solving led us back to the world of affordances, as represented by Wertheimer's analysis of types of solution. We found that the processes of problem-specification and problem-solution converge. Moreover, one type of "fine" solution requires a relaxation of subject-object dichotomization. We contrasted a logicist, representationalist examination of symmetry with one which considers symmetry a "rho-relation," one at a level of description other than that of that dichotomy. Consideration of solution of problems cannot proceed for long without a theory of motivation, i.e. without a theory of why one sets problems for oneself. In other words, we need to take into account affective and general motivational factors once more.

This chapter has focused on Cognitive Psychology, while including findings from fields within Psychology which are often mistakenly treated as irrelevant to Cognition. A fully-articulated CS would encompass cognitive psychology. It is as well to point out that a science dealing with knowledge should set boundaries for what we know and consequently what parts of our experience are authentic. It has been argued in this chapter that affect is also knowledge: that knowledge cannot be understood except with respect to cognitive development, nor cognitive development except with reference to the development of consciousness; that only a phenomenological approach to psychology can bear the massive burden of the research project suggested by this requirement; and finally, that in terms of our personal experience of the world, we should not be surprised to find it enriched by rigorous scientific analysis.

Further Reading

Gardner Murphy's (1972) is still the most readable history of early experimental psychology. J R Anderson (1989) is a very strongly cognitive-scientific account. Bolton (1979) gives a good introduction to phenomenological psychology. Chapters 2 and 3 in Stillings et al (eds) complement the account here well. Neisser (1976), though out of date, is lucid and worth reading.

3. Linguistics

Introduction

This chapter is a very brief introduction to Linguistics. There are two principal aims herein, apart from the obvious one of outlining a discipline which has historically been central to Cognitive Science:

1. To discuss language generically as a symbol system, like music and math
2. To point out that a full description even of linguistic behaviour requires consideration of operational knowledge.
3. To consider how the notion of situated cognition can be related to symbolic behaviour through the idea of context. This argument is very central to the whole book, so let's look at it in outline. Essentially, it is argued that the relation between the layers of language (syntax, semantics etc: see diagram 3.16) varies between tasks and with changes in the degree of restriction of context i.e. with the situation. Meaning is regarded as the province of an embodied person, not a particular layer of language. In terms of the theories to be discussed, we're concerned with finding a via media between formal grammatical theories of language and the alternative "cognitivist" approaches thereto.

Our path is the following:

First, we ask why such a discipline as linguistics exists, and what it sets out to study. We introduce the different levels of language. The context in which we discuss linguistics is its relation to computation. Consequently, there is a computational linguistics strand running through this chapter.

Secondly, we discuss the major schools within linguistics, starting with what has become known as the Chomskyan revolution. The going in this sub-section is unavoidably a little technical: however, the area is interesting enough to be worth the extra effort. We discuss the crucial concept of formal language theory before proceeding to other linguistic theories.

Thirdly, we discuss the role of non-linguistic knowledge in our use of language.

This discussion encompasses both the evidence from child language development (ontogeny) and language as a phenomenon in evolution (phylogeny).

This leads us to a discussion of the pervasive role of context. Initially, the effect of context is examined in syntax/semantics interaction.

We then discuss the multifarious uses of language, particularly as implemented in computational linguistics systems. An optional discussion of this latter topic brings us on to the summary of the role of context and of mind in linguistics featured at the end of the chapter.

3.1 Why Linguistics?

We are about to enter a minefield – linguistics is the most fractious discipline in this book, and the one whose controversies are fiercest – so, it makes good sense to ask "why bother?" Surely there is an easier way to approach the apparently natural study of language than to discuss a discipline whose stated mission of supplying a formalization of language has led to the formation of dozens of mutually antagonistic camps, whose basic conceptions are often couched in highly baroque mathematical formalisms? Can it be possible that natural language, the capacity for which except in rare cases is part of our common human inheritance, needs such a complex apparatus for its description? Amazingly, the respective answers are no, there is no easier way, and yes, it does seem that every verbal human being is the possessor of a structure whose complexity rivals anything in the universe.

We've noted already that behaviourism failed completely to give an adequate account of language. Not for the last time, we are confronted with a powerful systematically structured system which doesn't yield to atomism of any kind. Essentially, a full behaviourist account of language would have to explain every event in the child's acquisition of language in terms of the child picking up, passively and unsystematically, words and grammatical rules from an environment which readily affords such. On the contrary, it seems nearer the truth that the child actively explores their linguistic environment, and discovers grammatical rules almost in the manner of a scientist unearthing new laws of nature. Indeed, the child's linguistic environment is generally impoverished and does not feature the kinds of systematic rewards for correctness and punishment for mistakes behaviourism needs.

At the opposite end of the spectrum, Piaget's attempt to consider language development only as yet another manifestation of the coming to fruition of a general cognitive apparatus also fell short of the mark. Language, we're going to note, interacts with non-linguistic knowledge in its development (ontogenesis), but also has autonomous rules of progression. In fact, the development of the linguistic expression of conceptual structures can strongly depend on how readily available this expression is in the language in question. The interaction between thought and language is a tangled web which we consider at some length below. Let's also note, parenthetically, that Saint Augustine's (1.1) attempt to explain everything about how words get their meanings simply in terms of denotation is a doomed, quixotic, and quasi-behaviourist exercise. We have already seen the quagmire into which Fodor is led by taking semantic functionalism on board.

The diversity of human languages also gives pause. We consider in the next section (see discussion of $a^n b^n$) how in their heterogeneity, these 3,000 or so languages can yet have their complexity neatly quantified. Amazingly, in these formal terms the complexity of all languages falls within a very narrow band of frequencies in the spectrum of complexities which formal languages can have. In fact, artificial languages like Esperanto may have failed largely because of their simplicity: the genetic code seems to require something meatier. There are no irregularities in Esperanto: it seems that this is as much an impediment as a support in its attempts to become accepted. Every natural language has idiosyncracies: let's look at two such. The Gaelic "cailín"

(quite familiar in its anglicized version of colleen), meaning girl, is in fact masculine! Characteristic Irish perversity (and maybe perversion)? The Germans wouldn't do anything like that? In fact, the German "Fräulein" is also a gender-bender: it's neuter!

The phenomenal learning capacity visible in children's learning acquisition has led to the generally accepted conclusion that some kind of innate language acquisition device (LAD) is at work. We've noted that this, inter alia, in turn has led researchers like Fodor to a thoroughgoing innatism. For him, the development of conceptual structures is identical to the development of a language of thought, which must be similar in some fundamental fashion to ordinary language.

More interestingly, the issues relating to what form an innate grammar must be and the conditions whereby incoming strings of words can be decided on as conforming or not to that grammar have launched a thousand separate research projects (rather like Marlowe's Helen!). We have noted that natural languages fall within a certain limited range of complexity: likewise, work like Gold's (1967) demonstrates that there are no guarantees that an arbitrarily chosen formal language can in fact be satisfactorily learned. The other 999 papers deal with issues like equating the recognition of strings in a language to proving that solutions within finite time exist for particular classes of problem. Alternatively, they use the resources of set theory to demonstrate that, considered simply as sets generated according to some formal principle of generation (i.e. algorithm), the classes of formal languages fall into naturally-occurring categories here as well. Further-flung speculation maps this notion of algorithmic production to conscious experience through various types of physical process. Thus recognition by a grammar and computability, listability and the nature of the physical processes inherent in consciousness come together conceptually in a manner we discuss in chapters 5 and 8.

It should not surprise us, given the titanic scale of a native speaker's linguistic knowledge, that we are better off appealing for judgement on matters linguistic to such a speaker than our incomplete linguistic formalisms. We call the thought-structures by which an adult native speaker can (normally unerringly) decide on the acceptability of linguistic samples that speaker's "competence." This perfect structure might contrast with the occasionally Dan Quayle-ish standard of "performance" due to issues like tiredness, alcohol, the necessarily more difficult process of being a speaker rather than a listener, or whatever. We'll conclude this section by noting the levels at which native speakers can display their knowledge. (A native speaker of a language, roughly speaking, is one who has learned that specific language in infancy – *infans* = not speaking).

In the first place, the speaker might decide that a given word doesn't sound like X, where X is English, German or whatever. The German "zwei" does not sound like English, nor does the French "couille." We call this the *phonotactics* level. The Gaelic "nguí" is a *morphological* pattern which could not appear in English: we simply won't have words which begin like that! Morphology also deals with issues like the normal additions of –ed to create the past tense and of s to create the plural. Alternatively, it does be obvious that this clause is a Hiberno-English construct, unacceptable to users of standard English. That is a *syntactic* judgement. "Pigs sprout green wings daily" has

something *semantically* wrong with it, while if I now tell you I'm about to stop writing and go out for a beer, you might decide this is irrelevant and therefore *pragmatically* wrong.

So far, then, we've noted the following points:

1. Linguistic knowledge, the birthright of almost every human being, is one of the most complicated structures in the universe.
2. The grammatical theories which reflect this linguistic knowledge are correspondingly complex. We'll find that the field of linguistics is still in flux.
3. The process whereby children learn languages can be described computationally in the same terms as the process of deciding whether certain strings are acceptable or not. Moreover, we might find ourselves, along with Penrose (1989), pushing roots into areas of complexity theory and the deterministic nature (or otherwise) of physical processes which will gain purchase in chapter 5.
4. Given the incompleteness of our formal linguistic theories, we find ourselves relying on native speaker intuitions for decisions on correctness, in all their fallibility.
5. For spoken language, decisions on correctness are formulated on the phonological, syntactic, semantic and pragmatic levels. As we discuss written language, we'll encounter a more complex structure.

3.2 Computation and Linguistics

The relationship between linguistics and computation is a complex one. The trend to rigorous formalization of natural-language grammars in linguistics (Chomsky, 1957) coincided with the development of third-generation computer languages similarly characterizable by productions (see 3.3.1). However, "parsers" (see end od this section) for natural language (e.g. Tomita, 1986; Earley, 1970) and for computer languages are to a large extent different. The degree to which purely syntactic parsing (e.g. Marcus, 1979) can be useful will also be discussed later.

Thompson (1983) supplies a framework in which the relationship between linguistics and computation can informatively be commented on. He proposes the following schema: [see diagram 3.1].

The terms "linguistics," "psychology" and "philosophy" have their normal meanings. Linguistics we can define as the attempt to give a "formal" characterization of a grammar or a language (in Chomskyan linguistics, these are identical) i.e. a description couched in logico-mathematical terms. Computational linguistics is considered as the attempt to give a computational characterization of a grammar. The models developed therein can be of service to linguists (e.g. Karttunen) as can the technical apparatus afforded by computers' number-crunching in speech labs etc. Psycholinguistics research attempts to explicate the cognitive activity inherent in language, often doing so in computational terms.

We have already mentioned aspects of the philosophy of language in chapter 1. Theory of linguistic computation is a description of the communicative process in the abstract. Applied computational linguistics (ACL) is "the instrumental use of language processing" (Thompson, 1983). Informed discussion of ACL requires prior attunement

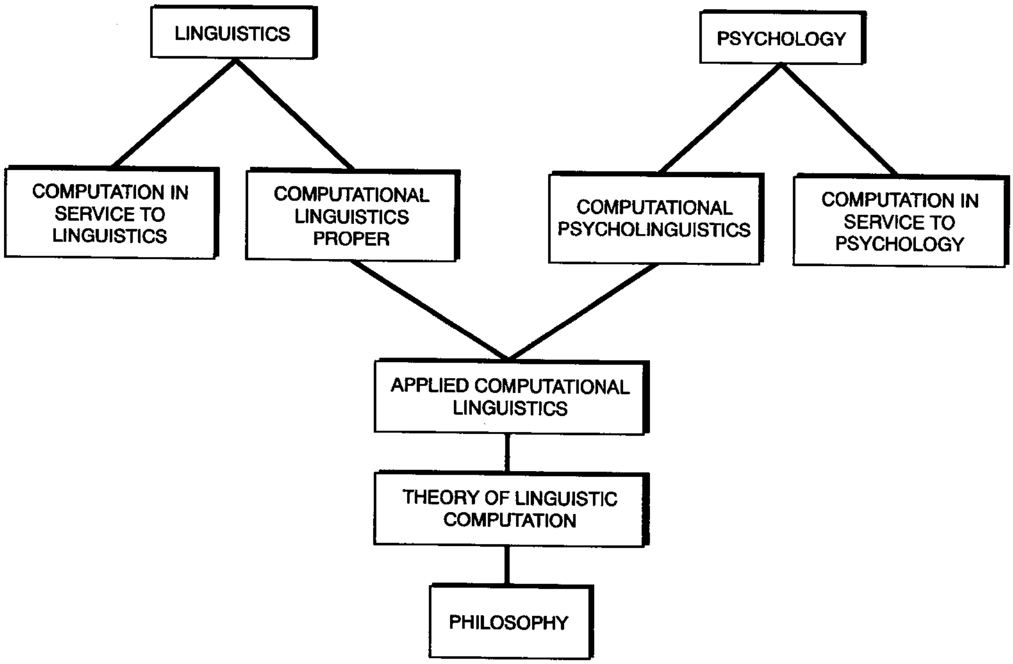


Figure 3.1

to the issues raised in the other sub-fields suggested by Thompson. Wahlster (1986) suggests the following guidelines as a sine qua non for an ACL system.

1. A subset of the output or input is coded in a natural language (NL)
2. Processing of this subset is based on knowledge about syntactic, semantic and/or pragmatic aspects of natural language

One of the best statements of ACL's achievements has been given by Grosz et al (1986). It should be noted, as for example by McTear (1987), that the building of these systems will often incidentally explicate some aspects of language processing by humans. The central commercial application has proven to be NL interfaces to databases: recent global economic trends have led to increased commercial interest in machine translation (MT): speech processing research is also a growth area.

It is necessary briefly to outline the current status of ACL systems before considering the relevant findings from other disciplines. Grosz et al (1986) make the following points, which still hold, with example systems being cited from the 1993 edition of the national software registry, available on ftp:

1. Semantic techniques have proven successful within very restricted domains
2. Syntactic parsing is now, up to a point, a textbook affair with several good parsers commercially available (Disco, a chart parser, UBS, a unification-based parser, and several GPSG parsers are available)

3. Discourse interpretation has handled concepts like language actions and intentions quite well (e.g. McTear, 1987)
4. Language generation has found difficulties in formalizing the interplay (e.g. Dale, Shieber et al) of linguistic and conceptual elements but some limited success has been achieved (again, Charon)
5. The problems thrown forth by anaphoric reference, and metaphor are only beginning to be dealt with (SLG features anaphor handling)

Wahlster (1988) adds the following:

6. Morphology packages are now readily available e.g. Morphix-3 and PC-Kimmo
7. "Language-independent" knowledge representation packages have been developed e.g. Kodiak
8. Likewise limited language generation and user-modelling packages (e.g. GUMS) have been produced. Several good integrated systems, which include syntax and semantics (inter alia) exist, e.g. ANLT (Grover et al, 1993).

Finally, research on speech processing has been progressing quite quickly. Despite occasional exaggerated claims (e.g. Fujimoto et al, 1987) the following is the state of the art:

9. Speaker-dependent voice processing systems, with vocabularies of up to tens of thousands of words are quite readily available. Research on speaker-independent systems using such techniques as grammatical representation of structural constraints on phoneme selection is proceeding with some success. We need a definition of parsing: it is to be considered as the use of any linguistic techniques whatsoever to derive a representation useful for the application in question. The representation can therefore be a database call (Boguraev et al, 1982), a conceptual dependency (CD) net (Schank and his school), a knowledge formalism (see chapter 5), or whatever is appropriate for the task in hand.

3.3 The main grammatical theories

3.3.1 The Chomskyan Revolution

We shall now examine the trend toward formalization in modern linguistics. It is worthwhile briefly to examine the origins of this trend. The notion that linguistics is a science and should therefore report on objective phenomena in the context of a theory relevant to the data is comparatively recent.

Bloomfield's work on the description of language, which superseded earlier prescriptive attempts, is a crucial work here. From the early 20th century, American linguists have sought to describe spoken language rather than fit written language into a set of categories. It has become *description* rather than *prescription*.

It is in this later American tradition that Chomsky's seminal work (Chomsky, 1957, 1965) is firmly placed. This work has had enormous influence on philosophy, psychology and linguistics as well as the Natural Language Programming (NLP) paradigms we will consider in chapter 5. Lyons (1977) describes these consequences well. This despite the fact it is difficult to see where precisely Chomsky's early work was a substantial progression from that of his contemporary peers, who also had

examined the formal devices like finite-state automata which we are about to investigate. In fact, his two major methodological dictates, that of isolating language from other cognitive systems and insisting on the modular encapsulation of syntax, may look like errors in the long term.

Before discussing Chomsky's work, two remarkable properties of language must be mentioned. The first is that language is infinitely creative. Every native speaker of a language can formulate and understand an infinite number of sentences. These sentences may in some cases include strings of the form $a^n b^n$ which a finite-state machine cannot recognize without great difficulty (Gazdar et al, 1989). These can be seen in sentences with relative clauses where the number of head verbs must equal the number of such clauses e.g. The cat *who sat* on the mat, *which was* on the floor….

Secondly, language possesses duality of structure (Lyons, 1977). Each level has its own rules, which linguistics theories must try and describe. These two main levels we've referred to as the *phonological* and the *syntactic*. Phonology, as has been pointed out, studies how sounds combine to form the elements of language. At the syntactic level, language is considered as the combination of meaningful units.

However, for his early work on formal grammars, Chomsky did not consider phonology in any detail. It is this work which is of most consequence for NLP, and which we will now outline.

First of all, what is a formal grammar? To say a formal grammar is a system which generates a formal language is hardly enough. Chomsky would add that the goal of linguistic theory is a formal grammar which would generate all and only the sentences of natural language. Thus, the key idea in Chomskyan linguistics is that of a generative grammar.

For Chomskyan linguists, a grammar is essentially a set of re-write rules which generate the sentences of a language. This is the essence of "Generative" grammar. The formal languages generated by formal grammars exhibit certain properties in common with natural language i.e. recursivity, ambiguity, duality of structure, creativity. We discuss these in chapter 7 in conjunction with other symbol-systems like music.

Other vernacular terms acquire new usages in our attempt to formalize language. The vocabulary V = a, b, c… is a set of tokens which forms the elements of the language. A sentence S is a string (e.g. aabc) of these tokens. The language L consists of all such sentences S each of which is a string over V. We shall also use constructs like NP (noun phrase e.g. the fat cats), and VP (a verb like "saw" or a phrase like "saw the fat cats").

To introduce the next notion, that of productions, let's consider a tennis example. For example, to beat André Agassi, you have to (among other things!) gradually force him out on his backhand side before playing a crosscourt. Let's write out this tactic as a grammar. We need at least two backhand (b) side shots, followed by a forehand (f) side one, for a successful rally, which we'll designate S.

Therefore, bbf, bbbf, bbbbf, and so on, are successful winning rallies. We want to be able to generate these and only these rallies; if we find ourselves generating losing rallies (e.g. bf), we are guilty of "over-generation." We need to introduce another entity,

"E" to safeguard ourselves. E is a "non-terminal," a term which I shall shortly define. Our rules are:

1. $S \rightarrow E$
2. $E \rightarrow f$
3. $E \rightarrow E$

If E=bf (rule 2), then by rule 1 S becomes bbf and we successfully leave André scrambling. To generate the more complicated rallies, we use the fact that E is defined in terms of itself (i.e. recursively). By rule 3, we can put as many b's as we want in front of "bf" before invoking rule 1.

What about the rules for generation of language? First, a distinction commonplace in Computer Science compiler theory between terminal and non-terminal elements must be introduced. Terminal elements (i.e. lexical items) are the words which ultimately appear in sentences: non-terminals are constructs like S, VP, etc. The total vocabulary V = VT + VN where VT is the set of terminal elements, and VN is the set of non-terminal elements. Re-write rules consist of a left-hand string which must contain at least one non-terminal, and a right-hand-string which is the result of the re-write. Let capitals denote elements of VN, lower case elements of VT. The following are valid re-write rules:

$A \rightarrow a$
$Aa \rightarrow a$
$ABC \rightarrow abc$

It has been mentioned that a grammar in the Chomskyan sense consists of a set of such re-writing rules. There are five basic types of formal grammar which we will examine in order of increasing power. We re-examine this notion in the larger context hinted at above in chapter 5 (see figure 5.4).

The first, the type 4 grammar, is also known as the finite-state grammar. This type has been used for many compilers and NLP programs. It is best to illustrate with an example from everyday-language which shows both the structure and the limitations of finite-state grammars (see Diagrams 3.2 and 3.3). Obviously, this grammar can generate the likes of "The man bit the dog." (We're being purist in having five types; most categorizations, including that used in chapter 5, call this type 3).

This kind of system clearly lends itself well to programming. Its expression in computational terms (like Backus-Naur form) is a trivial operation. However, as Chomsky (1957) proves, it is not powerful enough to deal with ordinary language elegantly. The detail of his argument need not concern us but it relates to the A^nB^n structure we noted with its recursive ethos.

On the other hand, it is only recently that tangible evidence has come forth (e.g. Shieber, 1984) to question the validity of type 3 grammars as a model for natural language. Both type 3, or context-free grammars, and type 2 context-sensitive grammars are examples of phrase-structure grammars (PSGs).

PSGs introduce non-terminal vocabulary elements. All phrase-structure re-writing rules are of the general form $X \rightarrow Y$. Type 2 grammars derive their additional power from rules of type $X \rightarrow Y/AB$. This rule can be expressed as follows:

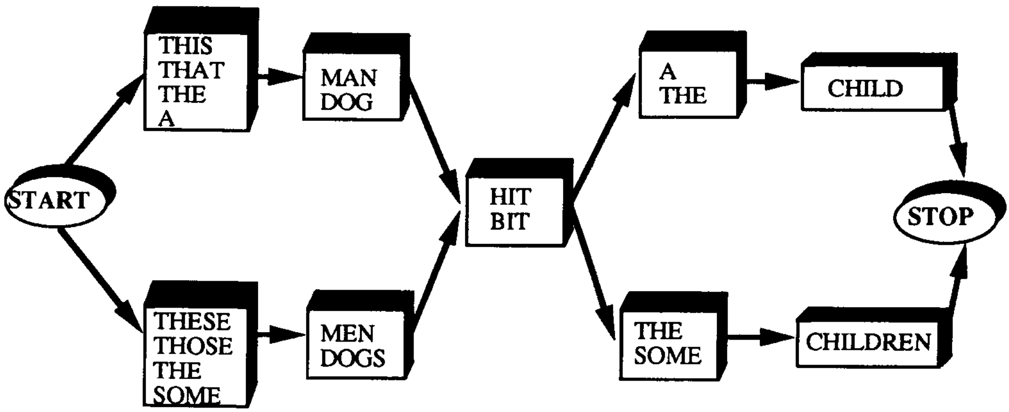


Figure 3.2

X is re-written as Y if A precedes and B follows X.

It will make our task of examining parsing systems easier if we have a short look now at the types of production rules which produce these bracketed sentences. Obviously, there are other issues within PSG of which homonymy – e.g. "bank," which has several meanings, depending on whether one means the bank of a river or a commercial bank, is homonymous – is the only one relevant here.

Here is a PSG system which generates the same type of sentence as the type 4 grammar above:

S → NP VP
NP → Art N
VP → V NP
Art → the, that, these…
N → man, men, dog…
V → hit, bit

Context-sensitive PSGs are certainly of sufficient power for NL generation. To these, Chomsky (1975) added the idea of transformations, which we consider below. TYPE 1, or recursively enumerable grammars and recursive type 0 grammars are likewise outside our present scope, being, as we shall see, too powerful for NL. We discuss these in connection with the work of Turing and Penrose in chapter 5. They are similar enough, for all practical and indeed several impractical purposes, to be taken together as type 0, which is what we do in chapter 5.

However, Chomsky's distinction between "deep structure" and "surface structure" is one which was for a time central to linguistics. It is relevant here, particularly for semantics-oriented NLP systems. Deep structure is an internal representation of the meaning of the sentence (here Wittgenstein would disagree as we saw in 1.3.3). In fact, Chomsky eventually disagreed with himself on this point. Deep structure arose from

Figure 3.3

the moment- which we shall henceforth refer to as "the incident"-that Chomsky decided to widen the scope of his linguistics in a new standard theory (Chomsky, 1965) which would treat semantics with the same formal rigor as syntax. The incident's consequences were that Chomsky retreated back into syntax.

Therefore, for some, linguistics turned from a prescriptive discipline into an attempt to mathematically characterize grammar. Chomsky's (1957, 1965) work has been massively influential in the field of NLP. That an innate system of at least the formal power of Chomsky's Type 3 grammar could be universal was a notion that excited many researchers in other fields. Grammars for human society, architecture, myth

(Campbell, 1982) and a jazz musician's improvisations (Johnson-Laird, 1988) are but a few of the speculations that emerged. Above, we considered the long rallies in clay court tennis as displaying this type of structure.

It is apposite to re-introduce a distinction between "Grammar" and "grammar." The former is the totality of a speaker's linguistic knowledge: the latter is syntax. Chomsky can be faulted, at least to some extent, for over-emphasizing the latter at the expense of the former. Thus, semantics is not treated formally with anything like the same thoroughness as syntax. Indeed, it is sometimes argued that Chomsky's major contribution has been providing the first framework in which phenomena like "tough-movement" can be discussed. " Tough-movement" is a phenomenon which manifests itself in sentences including a small set of adjectives e.g. tough, hard, easy. It was found, using Chomsky's analysis that the subject of such a sentence as "The party was hard for Bill to leave" is not "the party," but rather the clause "for Bill to leave the party." The same goes for the sentence: "It's easy to beat Andre Agassi."

The attack on Chomskyan deep-structures was two-pronged. Generative semanticists insist that "there is no clear-cut distinction between syntactic and semantic rules" and that the lexicon can take a role in grammar. Interpretative semanticists, on the other hand, move "deep structure" closer to the level of syntax. Chomsky's own later writings have tended to favor this conclusion which seems to have won. It may be argued that the demise of doctrinaire Chomskyan linguistics has been salutary. *Vive la différence!*

However, even agrammatical strings of words (e.g. talks IRA impossible), which obviously don't conform to any formal grammar, may yet be successfully processed. The transition from the laborer's single-word "Slab" to full use of syntax is, Wittgenstein argues, of a quantitative rather than a qualitative nature. It is unquestionable that we inherit grammars of a certain complexity. Yet processing can sometimes successfully occur without recourse to the rules of these grammars.

The general model due to the Chomskyan (1965) theory of transformational grammar then, is the following: deep structures (which arise mysteriously from a black box called "semantics") and comprise entities such as (**Mary is eager**). (**Mary pleases someone**) are transformed into surface structures by transformational rules. These syntactic structures are in turn relayed to phonological rules and so we gladly hear "Mary is eager to please." The syntactic structures are treated using the resources of formal language theory. As has been mentioned above, the major difficulties which arose concerned the role of surface structure in determining meaning. A quantifier like "some" completely alters the meaning of

"Women are dishonest"

to the completely politically and semantically correct.

"Some women are dishonest."

Yet it was difficult to cater for the pervasive influence of such quantifiers by reference to deep structures alone. Thus the confrontation between generative and interpretive semantics, which, as has been mentioned, is seen to have been resolved in favor of the latter. But where does this now leave us in our efforts to express a Grand Unified Theory of Languages (GUTOL) in formal terms?

3.3.2 The Counter-revolution

The problem outlined above about the role of quantifiers combined with other lacunae halted Transformational Grammar's advance. One critical issue we have raised is where exactly semantics fits in the schema. One possibly viable option is to introduce a level of logical form intermediate between "meaning" and "surface structure." I shall argue later that all this is rather pointless: in the meantime, let's look at the paradigm (Government-Binding: GB) which proposes this idea about logical form. (The minimalist program can best be understood in the context of GB as an attempt to subject the number of representations, steps in derivations as well as symbols to a principle of economy).

The first innovation in GB, which was formulated by Chomsky himself, was a tendency to put much more weight on the "dictionary" entries of words themselves (i.e. the lexicon). Secondly, in keeping with Chomsky's stated preference for rules which worked across all the languages of the world (i.e. his desire for a Universal Grammar), the syntactic rules, such as they were, were couched at a higher degree of abstraction than the relatively language-dependent notions of "Noun Phrase," "Verb Phrase." Look back on our phrase-structure grammar (PSG) in the preceding section. The GB statement of the first three rules would be:

$S \rightarrow \bar{\bar{N}}\ \bar{\bar{V}}$
$X \rightarrow \text{Specifier } \bar{X}$
$X \rightarrow X \text{ Complement}$

We wish this to generate "The company with which we've done business." There doesn't seem, so far, to be any major gain in efficiency. However, let's examine this rule. In general, $\bar{\bar{N}}$ is going to take the role of an NP: we are told that it comprises a specifier followed by $\bar{X}$. Thus, we end with "The ($\bar{X}$)." $\bar{X}$, in turn, can be re-written as "company" with complement standing for a prepositional phrase such as "with which we've done business." This general schema, slightly adapted, will work for VPs as well.

In general, sentences and verb phrases are conceived of as governed by a head, in particular a head verb, with an accompanying description of the agent and patient of the verb. Thus, "John broke his elbow" would be formulated.

Gov	Agent	patient
Broke	John	elbow

(In Gaelic, which like 19% of the world's languages is Verb Subject Object (VSO) order, that sequence is preserved for the "normal language": Bhris Seán uilleann). What's

happened to the determiners (his, the) etc? In NLP systems which use GB, these items are featurized at another level of description. Thus, "elbow" would have associated with it a marker indicating it had a determiner equal to "his." GB theory has proven an extremely rich formalism, and the attendant notions like X syntax have computational implications. Moreover, the idea that a symbol functions by virtue of head items which at various levels ($\bar{X}$, $\bar{X}$, etc), structure the subsidiary elements in their vicinity, is useful even for such systems as disparate in function as music and vision. In music, we find that as the themes develop, sub-themes are introduced, which in turn become the head items for further development. In vision, it's been speculated that recognition of shapes can best be done computationally (neurologically, no-one is quite sure) with respect to similar rules of well-formedness. According to this framework, we view a body by breaking the components down with "generalized cylinders." The torso is one such cylinder, the head another, the arms another: the "S" in this rule

$$S \rightarrow \bar{\bar{N}}\ \bar{\bar{V}}$$

corresponds to the whole body, with $\bar{\bar{N}}$ being a significant item like the torso, $\bar{\bar{V}}$ the head, etc.

It's clear that GB theory operates at a rather stratospheric level, is rather imprecise in places, and allows much room for particular interpretations. Not so the formalisms which have been developed in the framework, or on the fringes of computational linguistics per se. Here, the necessity for computational precision has forced linguists to come up with much more detail. A common tool of this particular trade is the use of features. Originally used for phonology, where for example the presence or absence of a vocal chord "hum" as one pronounces a sound yields the categorization "plus or minus voiced" (for example, the z in zebra is voiced and the s in silence isn't): features are now a common part of syntax. For example the verb "broke" has the following features: its category is a verb, its tense is past tense, and it expects an NP argument (e.g. an elbow). If we incorporate features like these into a PSG formalism – and note that the argument feature allows sentence constituents to interact – we have the beginnings of a Generalized PSG (GPSG). This system has proven computationally useful and is psychologically not implausible.

Alternatively, we may decide to put a huge burden on the lexicon, thus specifying much of what is handled by syntax in conventional theories. Categorial Grammar is such a system.

In introducing his functional unification grammar (FUG) Kay (1985) insists that language must be considered as a system for transmitting and encoding ideas. FUG is a grammar-writing tool, and is too powerful for NL in its undiluted state. (Karttunen and Kay, 1985) have shown how FUG can be applied to an extremely inflected, relatively free-word-order language like Finnish.

The sentence "Esa luki kirjan" (Esa read the book where kirjan is "book," luki is "read") can be legally written in any of the 3! (= 6) possible orders in Finnish. Phrase-structure rules are not appropriate here; subject and object relations are not given by word order. However, word order can have some influence; the sentence given above

tends to be interpreted as active, whereas Kirjan luki Esa tends to be interpreted as passive. Other orderings may e.g. stress that it was a book, not a newspaper.

Thus, structural configuration and prosodic contour are important for Finnish. FUG may be applied here to express the functional descriptions necessary.

Lexical functional grammar (LFG) distinguishes between rules about a word's syntactic role (c-rules) and its functional role (f-rules e.g. subject, object). At the end of the analysis of a particular sentence, the two descriptions must be interrelated. LFG has proven computationally extremely worthwhile. Other computational formalisms include Relational grammar, Tree-adjoining grammar and definite clause grammar, where the computer language Prolog is used to optimize the use of PSGs.

We've looked extremely briefly at the most currently influential alternatives to Transformational Grammar. Yet, by their authors' own admissions, none of these systems give a comprehensive account of all language. In the following section, it will be argued that the reason for this is the effect of non-linguistic operational knowledge. We need, in this context, to look at the development of child language.

We then briefly look at supporting neuroscientific evidence for the Nolanian viewpoint, and at Cognitive Linguistics, the theory of linguistics most compatible with Neural Darwinism.

3.4 Language Development and Linguistics

3.4.1 Thought and Language

Chomsky considers his work to be a theory not just of linguistics, but relevant also to psychology and philosophy. Chomsky is the current "high priest" of linguistics. I use this term deliberately and not pejoratively. It is ridiculous to exclude his politics from a discussion of Chomsky, and his claim that his intellectual and political activity are a unity forces question about his continual claims on moral high ground. Not even his many critics would deny that Chomsky still is the most influential linguist, whatever about the most correct. So, to find out about language, ask Noam: yet he has continually failed to explicitly acknowledge the shortcomings of his work, even when, as has often happened, the criticisms levelled have in fact forced him to change his mind. This autocratic attitude is precisely the politics which he criticizes so brilliantly. Yes, his intellectual and political activities are complementary: one is a precise mirror image of the other.

Some of his more excitable disciples (including Fodor) have argued that the ontogenesis of the language of thought is coextensive with the ontogenesis of mind and, less controversially, that epistemological issues can be greatly clarified by proper attention to language's role. There still are those who advocate the path of linguistic determinism, i.e. the notion that thought *is* language, or at the very least informs it greatly. This thesis attracted many followers this century and is entitled "the Sapir-Whorf hypothesis" after its main protagonists, Edward Sapir (an anthropologist and linguist) and Benjamin Lee Whorf (an insurance official for whom linguistics was a passion).

The kind of experimental evidence used to support this hypothesis focused on languages where certain concepts might be extremely strongly or weakly encoded. For

example, the Zuni language has an impoverished color vocabulary: by contrast, the Inuit people have an enriched snow vocabulary (admittedly of compound words), and the Gaelic language has a rich palette of words for "fog" and "rain." Native speakers of Zuni might be shown a set of colors A… D and, after a delay, asked to match a new sample against one of the remembered array A… D. Their failure to do this at the level of English speakers was seen as indicating an inability to encode these color concepts due to a restricted vocabulary. This type of result supports linguistic determinism: we're going to see evidence below from child development for the alternative "cognition" hypothesis.

Piaget, we have noted, insists that language is a species of thought. Let us try and reconcile these opposing viewpoints in some sense. What is thought, and what is language? We need to look at their evolutionary development in order fully to answer this question.

Signaling systems exist throughout the animal kingdom. One of the best known is the dance of the hive bee. A bee, having gone out to reconnoitre an area, performs a "dance" for the benefit of its colleagues on its return. Some superb research has demonstrated that the dance unfolds according to certain definite grammatical rules and comprises an account of where the richest source of pollen in the neighborhood is. Let's note two things about this:

1. Mind in nature manifested in the structured interaction of a variety of components: the bees' need for food, the flowers' need to reproduce
2. The structured "language" of the bee's dance

Thought as problem-solving also exists throughout the animal kingdom. A classic set of experiments by the Gestalt psychologist Ivo Köhler showed that chimpanzees were able to solve the problem of reaching a bunch of bananas by pulling up a chair to extend their reach. This is quite clever, and you and I both know people who wouldn't think of this, even if given a millennium to do so. So why not try and teach chimpanzees language? Their vocal apparatus is not all that good, so let them learn American Sign Language (ASL). Surely…?

Unfortunately not. Nim Chimpsky (yes, even in the 1960s and 1970s Chomsky had his vitriolic critics) and colleagues managed to pick up a few hundred signs for various things and some primitive rules for combination of these signs. Indeed, and this shouldn't surprise us given what we now know about the necessity for human non-precocious (altricial) development, at 12 months of age the average chimp had more to say than the average baby. However, the general consensus is that there is a bottoming-out due to an inability to truly refer to objects in the external world, independent of strong inner physical reactions incited by those objects (e.g. a banana will get the digestive juices flowing). We can, if we like, say that the language tokens have connotation (they mean something in inner idiosyncratic terms) but not denotation.

Where does this leave us? We accept that language and thought exist quite far down the evolutionary scale: however, ingenious attempts to teach an animal with which we share 99% of our DNA anything beyond the rudiments of language have failed. We'll begin outlining our overall perspective by noting that these results would

not have surprised the Russian psychologist Vygotsky. In his masterpiece *Thought and Language* (1934), he argued that the two were distinct in evolutionary terms. It is only with humans that thought becomes linguistic and language conceptual.

Perhaps I should now put the first of my cards on the table. If thought and language interact in this way, and their interaction is in some way idiosyncratic, as I argue below and in Ó Nualláin (1993), a GUTOL is an impossibility. The GUTOL would have to include, along with its formal system, operational knowledge, the whole of the intersubjective domain, and the forms imposed on experience by mythic/archetypal experiences.

3.4.2 The evidence from child development

We've noted that the most useful viewpoint to have on children's linguistic development considers them as research scientists in search of general laws. Even an infant's solitary meaningless babbling is directed experimentation (and not, as one of my students told me, the child's training to be a professor). In fact, perhaps unlike that of lecturers, the child's babbling is highly structured. I have already noted the voiced/voiceless (e.g. /d/ versus /t/, /v/ versus /f/) distinction: in general, the evidence seems to corroborate the following:

1. The child is actively experimenting with such distinctions
2. If a distinction appears early on in the child's babbling, it tends to be a correspondingly universal feature of the world's languages.

The voiced/voiceless dimension, one of the child's first forays, is quite universal over all human languages: the distinction between the vowel sounds in the French "rue" and "roue," inaudible to many non-native French speakers, appears much later.

As soon as the child has mastered the phonetic system and begins to produce strings of words in the native language designate, other regularities appear. The one we must look at here is the expression of thought structures through incomplete syntactic forms. (In the heyday of developmental linguistics, thousands of post-graduates waited fretfully to record the next utterance of a snot-nosed child rather like a neophyte waiting for her guru's next oracular pronouncement). One such thought structure is possession. Interestingly, it appears in English before the child has mastered the syntactic form:

> That John, dog
> That Dada nose

In general, old syntactic forms are used to express new concepts. This single fact gives the lie to the strong form of the Sapir-Whorf hypothesis.

However, the situation is a little bit more fraught. For example, negation, which is simply expressed in languages such as English and German is more difficult in French:

> I am *not* working.
> Ich arbeite *nicht*.

Je *ne* travaille *pas*.

Meanwhile, Japanese and Irish people just can't say no. In Gaelic, you can only deny a specific proposition, rather than say "no": this has in fact infected our English to the point that "yes" often means "no" in Dublin, which leads to interesting date rape trials. One can answer "Níl," meaning "there is not," but not specifically "no." In Japanese, there are different forms for negation. Even in English, however, there are different forms for negation as rejection (Don't), non-existence (There isn't) and denial (He didn't). Non-existence is expressed by its correct form only after being long established as a Cognitive category. If we accept negation as the root concept, which most developmental psychologists of the 1970s did, we accept that here is a manifestation of autonomous language development. In general, the conclusion from this field was that "new forms express old meanings, and new meanings are expressed through old forms."

3.4.2.1 Some supportive neuroscientific evidence

In order to support our notion of the separation of thought and language, it's going to help greatly if we can find some corroborative neuroscientific evidence. Damasio and Damasio (1992) supply just that. They posit three structures related to the language faculty, evidenced by dysfunctions specific to the brain areas assumed responsible for each structure:

a. A large number of structures in both the left and right hemispheres (see chapter 4) which process motor and sensory interactions with the environment and categorize them. A pathology associated with this is that patients with lesions in the area of the V2 and V4 areas of the cortex can neither see nor imagine colors.
b. A specific area near the sylvian fissure in the left hemisphere caters for the correct formation of words and sentences. Such dysfunctions as dyslexia are characteristic here.
c. Interlinkages between (a) and (b). The pathology here results from damage to the temporal segment of the left lingual gyrus. Patients can perform color-selection tasks correctly, but will say "red" for "blue."

We can look on (a) as operational knowledge, and (b) as purely linguistic knowledge. So far, the evidence is in our favor.

3.4.2.2 Cognitive Linguistics

It is the viewpoint of this book that language must be described in its own formal vocabulary as well as being interrelated with operational knowledge for full understanding of its role in cognition. George Lakoff's work may be regarded as perhaps a misguided attempt at Piaget's project of fully realizing language as a species of the more general notion of thought, or what Edelman (1992) refers to as "embodied concepts." For Edelman (1992), following Lakoff (1987), both syntax and semantics depend on a prior set of schemas like that of "container," "center-periphery" and "source-path-goal."

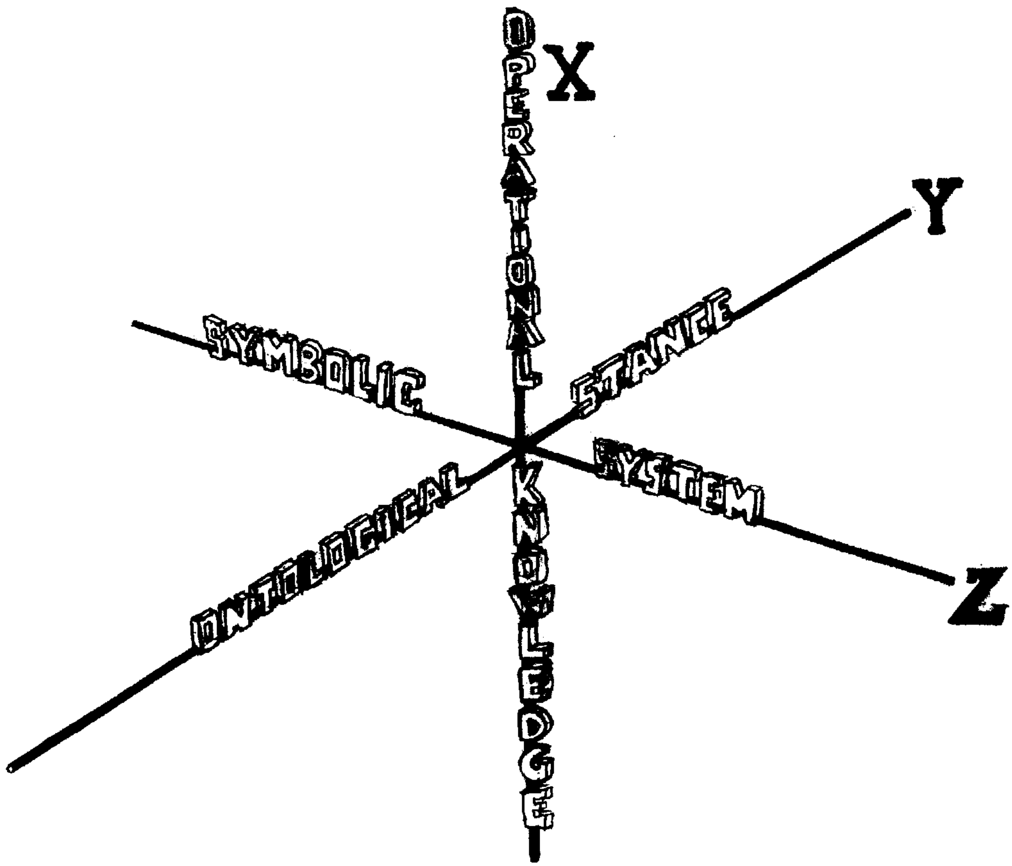


Figure 3.4

Even syntax yields to these schemas: syntactic categories are manifestations of the container schema (undoubtedly, Lakoff would be sympathetic to Piaget's notion of relativization as a manifestation of the general procedure of insertion). The head/modifier relations we saw exploited in GB would be an exemplar of the cognitive universal "center-periphery."

It is Lakoff's approach to semantics which is perhaps more instructive. Let us take just one of the five types which Lakoff proposes of a general construct called "idealized cognitive models" (ICMs) i.e. propositional such models. These last consist solely of base-level concepts i.e. entities, actions, states and properties. When associated with linguistic elements, we get a new form called symbolic ICMs.

These provide the mapping required by conventional semantic theory. It's worthwhile paying a little more attention to Lakoff's theory: it is the one which

Edelman favors as his pet theory of situated, embodied cognition and it provides one possible out from the troubling problem of grounding.

First of all, it is compatible with aspects of the ethos of the preceding section. The knowledge encoded there under category (a) is seen as the basis for ICMs. Apart from the propositional, there are other types of ICMs, including the metaphorical. All that is necessary for communication is that we should concur, if not agree (!):

> "The act of communication is the intending of the object as being what it is for both under the auspices of a symbol" (Edelman, p. 245).

This is precisely the viewpoint on meaning we arrived at in chapter 1 starting from quite different considerations.

There are some even more telling points made by cognitive linguists. We shall see in chapter 5 that some constructs like spatial prepositions are viewed as outward projection of the body and its activity. The notion Edelman emphasizes that concepts arise from the brain's categorization of its own pattern of activity is formulated thus by Mark Johnson:

> "An image schema is a recurring dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience" (Johnson, 1987, iv)

These image schemas, as mentioned above, include "container," "center-periphery," etc. Were cognitive linguists to concede formal autonomy to syntax, there stance would seem to me valid. But why should there be a privileged cognitive apparatus of this nature? We are back to the Chomsky versus Piaget debate, which Chomsky is seen to have won. Essentially, the evidence from phenomena like English past tenses and plurals as well as analysis of the formal language complexity of natural language points to a mechanism of a sophistication and consistency other than that to which we are accustomed.

A *via media* between the formalists and cognitivists can be found by admitting the autonomy of syntax; there may also be analogous syntaxes of music and math. It is as complicated as it needs to be for the conveying of thoughts, the main business of language. Every use of language has values along three dimensions, of which the syntactic (which to simplify we express as "symbolic") is just one. Let us now examine context.

3.5 Toward a definition of context

It's time now to draw some of these strands together. We hypothesize evolutionarily distinct strands which we shall simply label (oversimplifying somewhat) "thought" and "language" which weave together in the course of child development. We can identify this substrate of "thought" with many different types of knowledge, including the Piagetian notion of internalized action which we term operational knowledge. These separated strands form a tapestry of various hues and various knits. These hues and knits we're going to call "contexts."

Consider the sentence "I love you." Is that crystal clear, or what? Now consider it in the following contexts:

1. Mother Teresa of Calcutta speaking to the poor of the world.
2. Two lovers speaking.
3. Ross Perot speaking to Bill Clinton.

We obviously now have, superimposed on the words themselves, a whole plethora of other considerations to do with intentions and situation: in short, with context. That simple sentence can express the Greek notions of agape (1) or eros (2) or the notion of brutishly contemptuous sarcasm.

Let's take this a stage further. For the situation envisaged in (2), the speaker could be understood speaking in initial letters (ILY) or, at a guess, backward (YLI). In the schema of figure 3.16, all that's necessary for full extraction of meaning is "social context" and "letters."

Similarly, the sentence

> "Tighten the nut on the bicycle in the garage!"

can be a request to get a simple job done, or alternatively a heartfelt plea to a child to get himself and his bicycle out of the house (quickly). The technical problem illustrated by this example is called prepositional phrase attachment: what is significant about it for our purposes is that there is no way by which we can resolve the ambiguity therein on linguistic grounds alone: the context must be taken into account.

With this in mind, I suggest that context in language is precisely the interaction of linguistic and other knowledge. Our tapestry includes different hues and different weaves as context changes. In other words, the laws interrelating non-linguistic and linguistic knowledge are going to vary greatly as context changes. Not only that: we can restrict a context, as in example ii), and our apparently clear-cut stratification of language disappears. Letters (level 2) seem to interact directly with social context (level 8) without any regard for intermediary stages. In short, as context is restricted, the levels of language collapse into themselves.

That, therefore, is the reason why linguistic models which attempt to separate "syntax," "semantics" and so on by putting them into neat, separate boxes simply don't work. In fact, it might be argued that this is basically a Cartesian error: it is talking about this abstract entity called "language" without reference to how it is actually used (see next section) in the world. Syntactic relations, in a sufficiently restricted context, can give the type of information normally viewed as semantic.

Let's take an example. We can use extremely similar systems to perform a syntactic parse of a sentence as to perform a full analysis of meaning, if the latter task is being done in a sufficiently restricted context. Both tasks involve traversing nets. In the former, we use a computational device called a transition net: in the latter, we adapt this (only slightly) to form a transition tree. If you care to take my word for this and/or don't feel disposed to follow some computational linguistics technical details, you can safely skip 3.5.1

3.5.1 Transitions and syntax

What is a transition net (TN)? How can TNs capture syntactic structure? A TN is a series of nodes connected by arcs. These arcs can be traversed if a condition attached to the arc is fulfilled. The condition may be appearance of an NP or as is the case with semantic grammars, a specific word, or series of words. In any case, the traversal of an arc may require traversal of an entire subordinate net or tree.

An example will illustrate. A fragment of English can be defined as follows:

1. S → NP VP
2. NP → det common Noun
3. NP → proper noun or pronoun
4. det → a, the
5. VP → V NP

The corresponding TN looks as follows (see Diagrams 3.5 and 3.6, which includes also the possibility of adjectives).

Augmented TNs have registers which retain records of features or partially completed parse trees. Each of these registers has an action associated with it. The register may, for example, note the fact that the subject of a sentence is plural. In generation, this action will transform the verbs correspondingly. Obviously, the augmentation adds considerably to the power of the grammar.

We have suggested an ATN structure for a subset of English ie noun phrases (see Figure 3.6). This by no means models all English noun phrases.

It should be noted that "category" first tests whether the incoming phrase is of a certain type, and then removes the phrase from the input if the test succeeds. (Figure 3.7). "Parse" follows a network right to its end.

"Parse" is used in the same way in both ATNs and AT Trees ie as a directive to traverse a sub-net.

We now add four basic types of operations in net and tree traversal of language representations. We have looked at "Parse." The second, SEQ, is appropriate for items like determiners which require only one test. Graphically, it looks like this (see Diagram 3.10, which is a seq over NP and VP).

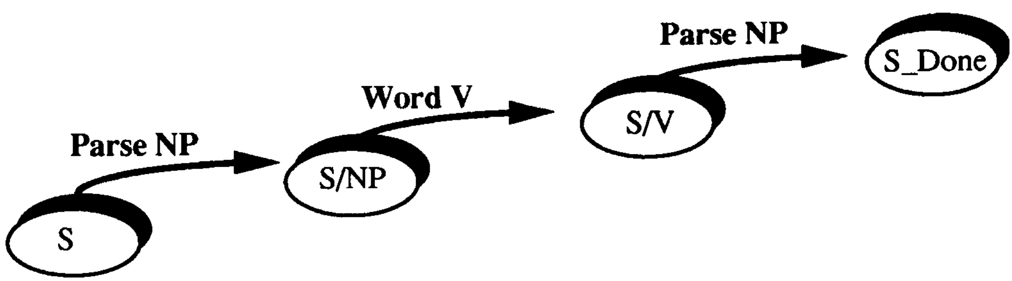


Figure 3.5

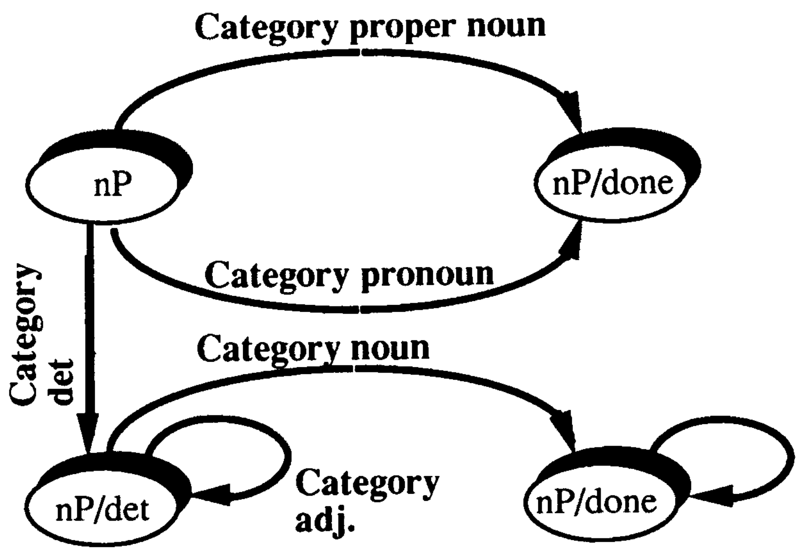


Figure 3.6

"Either" can be used when two non-jump arcs (jump arcs don't need a constituent to be traversed) emerge from the same node. An example is the one-step traversal of jumps which consist either of a proper noun or pronoun (Diagram 3.8).

A noun may have an number of modifying, informative (etc) adjectives in front of it. The test for such items is "optional," represented in Diagram 3.9).

The full parse of the "man bites dog" sentence is given in diagram 3.11. Figure 3.3 hopefully elucidates the above explanation!

3.5.1.1 Transitions and Semantics

It should be clear that the term "semantic grammar" is almost a spoonerism. Yet it is still used for that application of AT trees (ATTs) in which the transitions can be specified "semantically". Thus, to take but one example, instead of specifying (Parse NP) we can now do (Parse OBJECT).

ATTs differ from ATNs in the following respects:

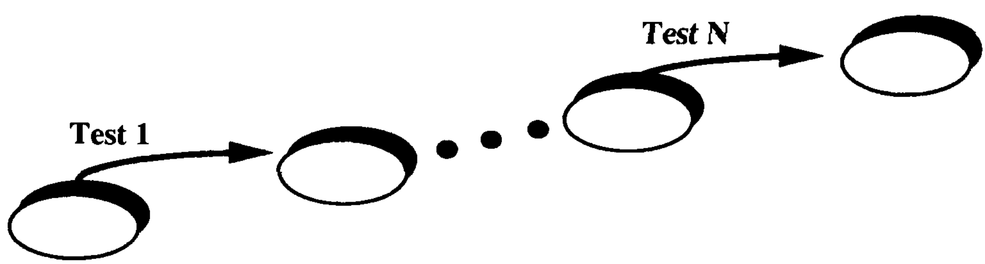


Figure 3.7

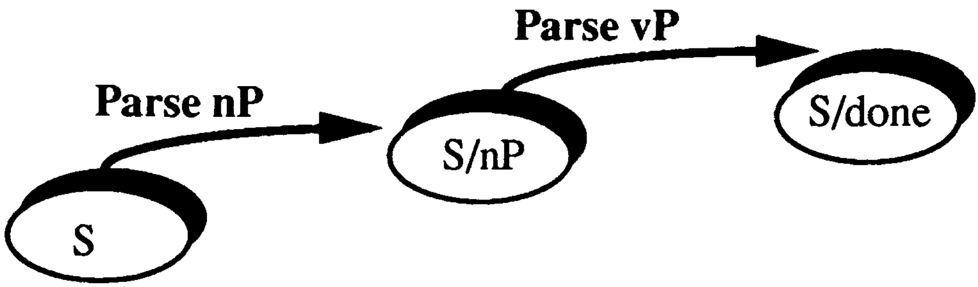


Figure 3.8

1. Arc transitions may require specific words rather than syntactic elements
2. Arc transitions may be specified "semantically." In this chapter, we should not be surprised by a syntactic relation yielding semantic information. When an object is not specified, it is preceded by an upward triangle in the top-level description (see Diagram 3.12).
3. Values are attached to the trees so specified, and these values normally form the basis for computation of the parse-result.
4. These values are terminal-elements in the vocabulary. Our formalism specifies such values with a downward triangle in front of the name of the tree which these values are intended to replace.
5. TTs do not allow backtracking.
6. ATNs allow more than one arc per mode.

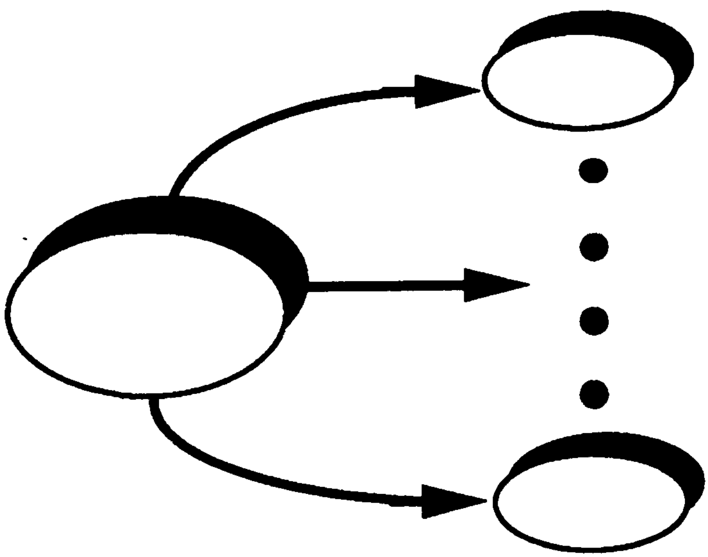


Figure 3.9

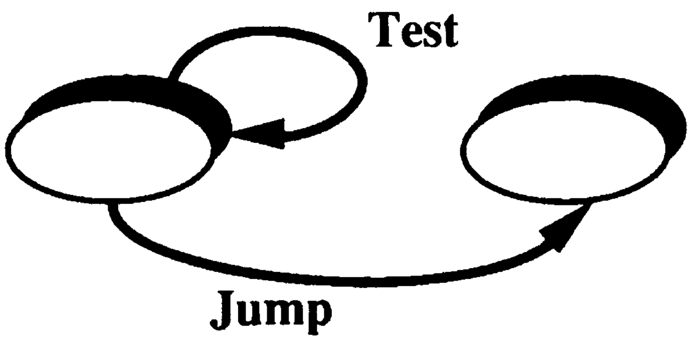


Figure 3.10

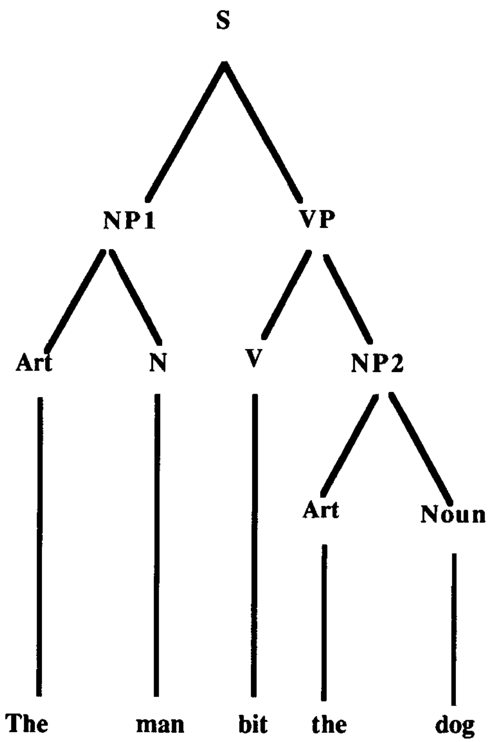


Figure 3.11

As an example, let us look at Diagram 3.12, which is a small subset of a "semantic grammar" system.

The system can handle the following grammatical questions:

Where is the national gallery?
Where is the taxi?
How can I get to the national gallery?
How can I get to the taxi?

It can also handle several ungrammatical questions, of the type that speakers of Hebrew (which often does not use the verb "to be" in the present tense, for interrogatives and like Russian, omits articles) may ask, for example:

Where taxi?
Where the taxi?
How can I get national gallery?

This facility is due to the jump arc at the bottom of (3) in figure 3.12 marked "Noise."

The value attached to the top tree, ie question, is a search procedure specified by the subordinate trees. Let us take the sentence "Where is the taxi? " as an

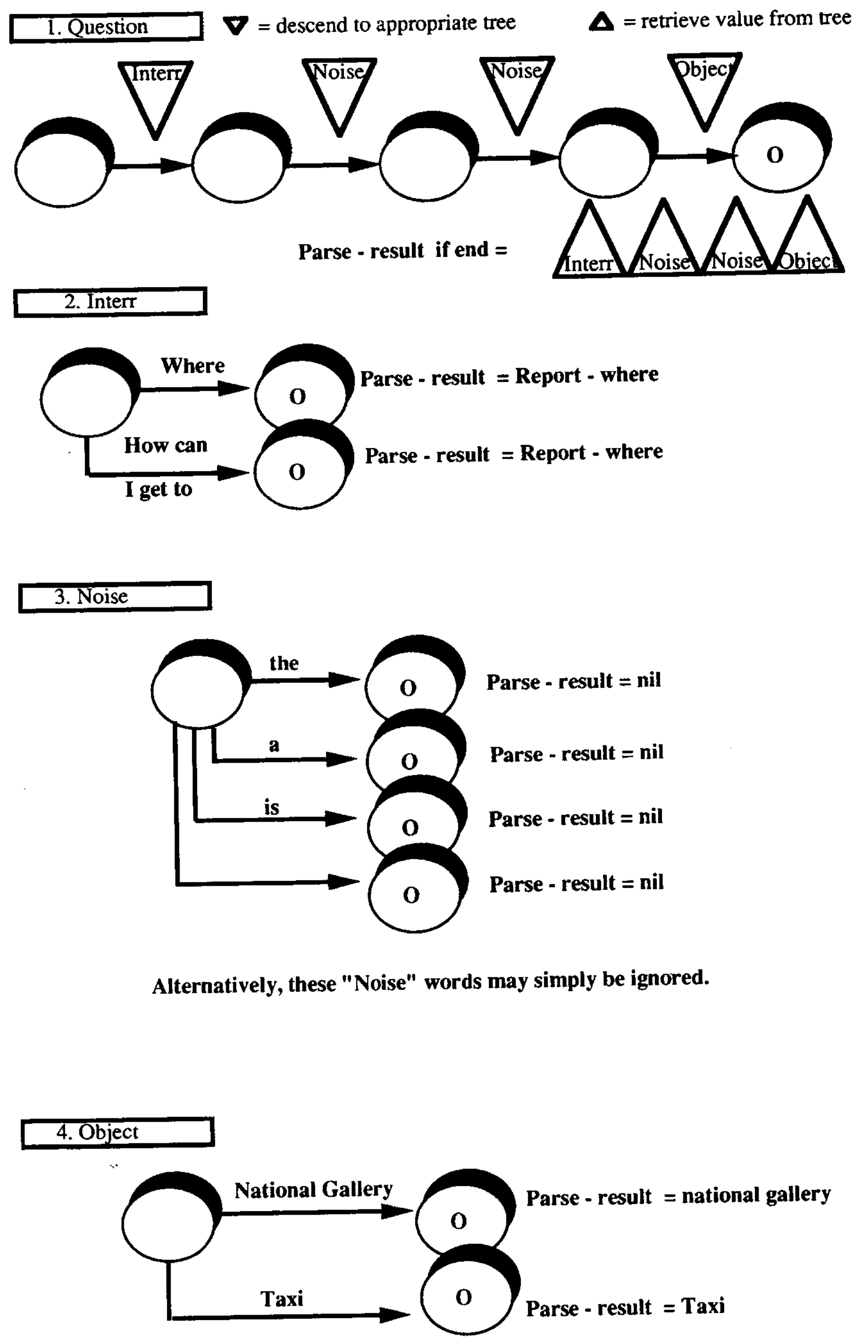

1. Question
= descend to appropriate tree
= retrieve value from tree
Interr
Noise
Noise
Object
O
Parse - result if end =
Interr
Noise
Noise
Object
2. Interr
Where
O
Parse - result = Report - where
How can
I get to
O
Parse - result = Report - where
3. Noise
the
O
Parse - result = nil
a
O
Parse - result = nil
is
O
Parse - result = nil
O
Parse - result = nil
Alternatively, these "Noise" words may simply be ignored.
4. Object
National Gallery
O
Parse - result = national gallery
Taxi
O
Parse - result = Taxi

Figure 3.12

example. The result is, in whatever programming language is being used, a data-base query for Taxi.

How is this achieved? First of all, we see that Question, the top tree, requires the values being brought up from the results of traversal of the lower trees.

1. Inter results in Report-where (in the sample here)
2. Noise twice results in nil, because it does not add any information
3. Object produces taxi.

Therefore, we've looked at two systems of almost identical computational structure. The ATN produces only a syntactic parse: however, the same mechanism in a more restricted context can elicit the semantic relations necessary to answer questions.

Had we restricted context a little further, single words might have sufficed: further still, and single letters might have done. This is our first venture from the world of grammatical theory into language use. We've already found a new use for the regularities of structure treated by syntax. The central plank of the argument in this book is that mind can be studied only in situ, as an organism's interaction with its environment. We should not be surprised if we are surprised again by the polymorphism of language-thought interaction.

Consequently, we abandon the syntax/semantics dimension, as conventionally considered at this point. To correctly study language, as is the case with cognition in general, we must consider person and environment together. The meaning derives from their interaction, not rabbits plucked from a "semantics" black box.

3.6 The multifarious uses of Language

Let's widen our net (I'm tempted to say broaden our context) a little by looking at the things we do with words. It is standard linguistics at this stage to distinguish between the information conveyed by a string of words and the intention which that same string attempts to realize:

> Would you like to keep on reading until you understand the argument?

can be interpreted at one level as an inquiry about what might please the reader, and at another (the perlocutionary) as a warning against jumping to premature conclusions. However, the situation is even more complex than that. Let's recap on the argument of the previous section before we elaborate on precisely how complicated the situation is.

The notion of a fully-realized formal GUTOL has been abandoned. The essential reason is that linguistic knowledge interacts with non-linguistic knowledge in idiosyncratic ways peculiar to specific contexts. Moreover, the stratification of language into well-defined levels ranging from the wholly conceptual (semantics/pragmatics) to the wholly structural (syntax) is now seen as artificial. Syntactic relations in a sufficiently restricted context can yield meaning, as indeed can a simple string of letters given further restriction. We need to look at what task is being done, and how restricted the context in question is. For the moment, it's worth noting that there might

be a useful distinction between meaning (for a user of language) and semantic relations (which the speaker might use as a means to give meaning).

Let's now look at a set of possible tasks:

a. Syntactic analysis. It may be the case that all we want to do, as in the manner of schoolteachers, is determine whether a given string is grammatical or not.
b. Use of "syntactic" methods to derive "semantic" information in the manner of semantic grammars.
c. Mapping to a scheme comprising a model of a set of actions. We've noted in the discussion of Piaget that certain such stereotyped schemes must exist.
d. Mapping to a set of logical atoms. A good example of this is reading about the politics of a country, other than one's own, in a foreign language newspaper. Somehow, all the familiar characters are there!
e. Processing of agrammatical strings "Hotel arson explosion" or even initial letters (ILY in a marriage proposal scene).

We have at least two orthogonal axes on which these tasks can be plotted:

1. degree of restriction of context.
2. the specificity of the output e.g. do we want a single fact or a motor sequence?

Not entirely coincidentally, all these tasks have also been computationally attempted. We have seen how (a) and (b) are done in section 3.5. (c) is done by the system developed by Schank and his colleagues. (d) has been attempted by a variety of researchers, particularly Nirenburg (1991). (e) is an application of word expert parsing (Small et al, 1982), where linguistic knowledge is all encoded at the lexical level.

This vast spectrum of language use, coupled with our findings on ATNS and TTs, have led us to abandon the received wisdom of absolute syntax/semantics (as meaning) separation; the distinction is obviously often inappropriate for computational purposes. To understand language, we must consider the language user in her environment. Meaning derives from this interaction of speaker and environment, not by appeal to a "semantics" black box after a syntactic parse: "In order to carry out referral, a formal representation must become an intentional one… this requires a consciousness and a self" (Edelman, 1992, p. 238; see also section 1.4.4.4 of this book).

At the very least, we must separate "semantics" and "meaning." We can sometimes usefully view the semantic level as a theory of the domain in which the person is embedded. This theory can be expressed in image schemas (or some other consensually validated "mentalese"), or if the domain is the clearly laid-out suburbs of Wittgenstein's "city of language," a formalism like set theory. It can trivially be proven that these representations can be described using the resources of predicate calculus; this does not commit one to a belief that predicate calculus is an appropriate psychological model. On occasion, the semantic level can be bypassed entirely, as we've already seen; derivation of meaning is a different if overlapping issue to semantic analysis.

Readers lacking an interest in computational linguistics can safely proceed immediately to 3.7.5.

3.7 Linguistics and Computational Linguistics

We've already found it useful, in considering the relationship between syntax and semantics, to make reference to computational linguistics techniques. The syntactic act of finding the main structural components of a sentence, we found, would in a restricted context afford semantic information. To show just how more complex the situation gets when we move across languages, let's consider the sentence (due to Carbonell et al, 1988).

"John took the cake from the table. He washed it."

Normally, the referent of the "it" (the anaphoric reference) is resolved only with reference to semantics (tables, not cakes are normally washable) and/or pragmatics. We call the latter activity discourse interpretation. However, let's look at the translation of this sentence into other European languages:
1. John a pris le gateau de la table. Il l'a nettoy*ée*.
2. John nahm die Torte von der Tisch und er putzte *ihn*.
3. John cogio el pastel de la mesa y *la* lavo
4. John ha preso il pasticino de la tavola e *la* ha lavat*a*.

Only in English, therefore, is it necessary to analyze beneath the syntactic level to semantic or other levels in order to resolve the anaphor in question. Indeed, in the Italian example, the necessary information is (as underlined) available twice over. CL has been extremely useful in highlighting issues like this. It has, on occasion, not only forced linguistics to give more computationally tractable accounts of its theories, but also introduced rigor where there might have been only vagueness followed by polemic.

3.7.1 Applied Computational Linguistics

3.7.1.1 Overview

The applications considered in this section fall into three main teleologically-derived categories. Other applications e.g. text generation, text scanning are not as relevant here.
1. Natural Language (NL) interface to data bases.
2. Machine translation.
3. Speech Processing.

We shall, for historical reasons, deal with MT first. In all cases, it will be noticeable that the systems described here work well only within sub-languages.

Some AI work, e.g. that of Schank et al (opera cit.) have been concerned with building "NL understanders." The representations therein produced may be used for either tasks (1) or (2).

MT is historically significant because it exposed for the first time the difficulties inherent in NLp. The early English-Russian work (Weaver, 1955) foundered because of an underestimate of the inherent complexity of language. The translation produced

tended to be massively ambiguous because of a failure to formalize the knowledge involved in the area, and thus disambiguate. Weaver's inspiration that symbols could be crunched like numbers with techniques like "statistical semantics" was attenuated in scope. Yet the perceived relative failure of other NLP techniques has recently led to a comeback for statistics (see chapter 5).

Analysis of English-Russian equivalents of the words "coach, lose, set" yields a 2040-way ambiguity when the number of different meanings each of these can have in Russian is multiplied. Moreover, Russian often omits articles (Nirenburg, 1987). The result is great difficulty in achieving the bi-directionality from English to Russian and vice versa which is desirable. With that in mind, we shall now consider what actually has been achieved.

3.7.1.2 Machine Translation

Both Nagao (1988) and Tucker (1987) describe the variety of approaches for MT. The algorithmic details we shall consider in chapter 2. It suffices for the moment to distinguish between:

a. the commercial approach which uses a well-defined sublanguage in a commercially viable area e.g. weather-forecasting.
b. Approaches which concern themselves with more sophisticated text, different categories of text and improving quality. (Nagao, op cit)
c. The AI approach which treats translation as problem-solving.
d. Probabilistic approaches: see Bayes in chapter 5.

Within these approaches different techniques (considered below) may be used. The first or direct approach does not construct an IR (intermediate representation) but maps direct from source to target text. A great deal of preprocessing of e.g. idioms and prepositions is first necessary. The Georgetown MT system (Toma, 1977) and its close relative, the EU's SYSTRAN (Zarechnak, 1979) are two instances here. The latter in particular has proven quite effective (Tucker, 1987) but pre- and post-editing are necessary. In other words, someone has to clean up both the input and output texts.

SYSTRAN, much updated, is now available on the web at:

http: //babelfish. altavista. digital. com/cgi-bin/translate?

The speed with which it produces translations of English back and forth to the main Romance languages at least gives pause with respect to the future of CL research. We need more powerful generalisations therein really to justify the expense. For example, Barwise and Cooper (1981) speculate that the semantics of English noun phrases are a principled subset of a much larger set of possibilities.

Transfer-based systems attempt to catch more subtle constructs by producing an IR. (Intermediate Representation, such as the syntactic parse we noted above). Taum-Meteo is a highly successful semantic grammar system with an near 100% success rate. The Taum group produced their system in response to a need for translation of the

weather forecast between English and French. Metal works in the telecommunications domain with a 45_80% success-rate.

(Nirenburg et al, 1991) attempt Knowledge Representation (KR) in a manner analogous to early Wittgenstein. All such systems must eventually address themselves to the problems inherent in the "logical atomist" ethos, if they intend to venture outside restricted contexts. Recently, Nirenburg shifted his attention to the fuller KBMT framework. With the recent ratification of NAFTA and further translation requirements from the EU-particularly for documents like fire regulations where translation is mandatory-it looks as though MT will capture an ever greater share of the worldwide $25 billion translation market.

3.7.1.3 NL Interfaces to data bases

It should be noted that NLIs are to date the most commercially successful application of CL. We shall outline the historically most important systems before looking at criteria for their assessment. There is a general consensus (Grosz et al, 1986; Bates et al, 1984; Hendrix et al, 1987) about the appropriate criteria.

Woods' work (1969, 1972) on the lunar rocks project was the first to establish a definite paradigm within NLP syntactic parsing ie ATN theory and method. This paradigm has been examined.

Woods' system answered questions in a very narrow contextual range. Burton et al (1976) addressed themselves to the issue of how to specify the domain of knowledge in a manner that did not require analysis at the level of conventional syntax (i.e. S, NP, VP, etc). The resulting method, the "semantic grammar" (SG), was used by Waltz to answer questions about planes and we've looked at it at length.

However, it was Hendrix and his associates (1977) who first developed programs which allowed people to write their own natural language interfaces (NLIs) without, so to speak, re-inventing the wheel. From the time of their LIFER project, constructing an NLI became a matter of writing applications for a general parsing machine.

It should be mentioned that considerable difficulties still remain. Thompson (1983) comments that a skilled programmer with considerable knowledge of language structure remains a prerequisite. In the same vein, Grosz et al (1986) comment that "the domain analysis to create such a grammar and the design of the grammar itself" still require "expertise in NLP. "

LIFER consists of:

1. a set of language specification functions.
2. a parser.

Hendrix et al (1978) comment that it attempts to emulate certain procedures performed by technicians. He adds that the use of an ATT, rather than an ATN, leads to several new properties.

LADDER (Hendrix et al, op. cit) was one application of LIFER. It answers queries on naval data and consists of three parts. It is the first, an NL parser, that we are most interested in here. IDA (intelligent data access), the second component commences the access of data. FAM handles the management of files.

INLAND's major innovation is its ad hoc grammar for its finite set of queries. This type of grammar allows questions of these forms:

How many ships are there with length greater than 300 feet?
What is the length of the Kennedy?
Where are the Nina, Pinta and Santa Maria?

And so on.

IDA breaks these questions down into search patterns e.g. ((Noun e.g. Kennedy) (? length)).

Harris (1984) wrote a system called INTELLECT with a specifically commercial application, also based on SGs. Like Schank, he founded a company (artificial intelligence corporation). Winston (1984) described INTELLECT, which answers questions on the Fortune top 500. Recently, Harris has produced "English Wizard," a follow-up system.

Hendrix's successor to LIFER, called Q+A, is described in Kamins (1985). It consists of three components.

1. a non-relational data-base access system.
2. a text editor.
3. an NLI system called Intelligent assistant (IA) which helps in the creation of domain-specific applications. IA has a built-in 400-word vocabulary, a database and dictionary, and an interactive knowledge-acquisition program which allows the user to add lexical knowledge. The vocabulary includes 250 non-terminals.

Q+A is the first system we have examined which features a programming language other than Lisp. In Q+A, the syntax is expressed as Lisp data structures and the semantic routines as Lisp procedures, but the parsing algorithm is implemented in C and assembler (Hendrix, 1987). Compilation into custom p-codes to run on a virtual machine speeds execution. We find cause to comment on virtual machines in chapters 4 and 8.

Q+A has been enormously successful, featuring in the top five best-selling software products in the USA (Wahlster, 1988). However, Wahlster (1986) notes the lack of flexibility in the grammar and the restriction of the NLI to data-base access. Both problems are due to limited space.

TEAM (Martin et al, 1984) features a schema translator in Prolog, while its other components are in Lisp. It runs on Symbolics LM_2 Lisp machine. Domain-dependent components include the lexicon, conceptual schema and database schema. These must be re-written in full for each new application. The domain-independent component includes the following:

1. a parser and grammar
2. semantic translators, which convert sentences into BSF (basic semantic form) which is a CD-like representation
3. pragmatic and scope-determining processes
4. the above-mentioned schema translator

5. a basic vocabulary and taxonomy

This distinction between domains will be featured again in the forthcoming appraisal of systems.

3.7.1.4 Appraisal of these systems

Grosz et al (1986) in their introduction, propose the following 8 categories for use in appraisal of systems:

1. Modularity: this concerns (a) the separation of domain-dependent and domain-independent knowledge, b) separation of the processing modules (e.g. syntactic and semantic modules)
2. Integration: the extent to which the information from each module is brought together into a single analysis.
3. Problem factorization: related to modularization. This issue concerns the extent to which each module is performing its task. Is the syntactic module operating purely formally, or is it inappropriately required to do reference evaluation?
4. Transportability: moving between domains
5. Habitability: Does the system allow for human error? (e.g. misspelling, elliptical input)
6. Extensibility: Ease of transportability and of extending the allowed language
7. Speed: of response
8. Veracity: The extent to which the human cognitive function is modeled.

This category is fairly irrelevant, insofar as we know very little about human LP and the small amount we do know suggests that the representation paradigm is to some extent inappropriate (see above).

Wahlster (1986) introduces a ninth category:

9. Transmutability: The extent to which the system can adjust to different types of usage.

Schank stresses a commercial sine qua non:

10. Updateability: can the system be adjusted to react to quick change eg. in the stock market?

Harris (1984) would insist that NLP systems be able to interface with other computer processes e.g. graphics, data bases. We will term this:

11. Compatibility

3.7.1.5 Speech Processing

Few areas are more prone to hyperbole. However, in recent years both Apple's Plaintalk and IBM's and Dragon's systems have brought this technology in an advanced form into the marketplace.

The more enlightened work in this area e.g. HWIM (Bruce et al, 1982) and HEARSAY (Charniak et al, 1985) has indicated the necessity for including other

linguistic and non-linguistic knowledge. The identity of the word input in human hearing seems to be guessed by a weighting of the evidence from these various sources of knowledge. Thus, we return to the central fact that language is massively hypothesis-driven. It is unlikely that the transduction from longitudinal waves to shearing of hair cells which is the basis for human audition yields information as massively complex as that required by a pure engineering approach (Allerhand, 1987). However, context can be so specific that a single phoneme could activate a scheme.

HWIM includes 13 different types of knowledge, ranging from the acoustic-phonetic to the strategic (Bruce, op cit). By contrast, Allerhand (1981) simply considers the "discrete time-varying signal" which must be mapped onto a symbolic form. His own solution, like that of Carson's (1988) is to formolize grammatical constraints on the sequence of phonemes allowable. We've discussed these constraints with respect to native speaker intuitions on phonology. The latter may yet win out, if the research projects based on statistical approaches can be said to be part thereof.

3.7.1.6 Language "understanders"

The scare quotes are deliberate. A problem with ACL is the degree to which people are willing to attribute intentionality to the CL systems. This argument appears in chapter 1, has been flogged to death elsewhere, and we won't worry any further about it. What we will discuss here under this heading is a series of systems which develop IRs which can be used for paraphrase, DB query, or translation. Wahlster (1988) stresses that knowledge representation (KR) is a crucial issue here. Our full discussion of KR is in chapter 5.

KRL (Bobrow et al, 1977) focuses on descriptions of objects. Both McDermott (1981) and Wilensky (1987) fault it for its lack of denotation and Winograd has abandoned this quest. The more successful KL-ONE (Brachman et al, 1985) insists on frequent use of structured inheritance nets as well as of descriptions. A parser has been developed in this framework. Woods (1984) describes a use of KL-ONE for NL interface to data bases.

Wilensky (1987) adduces a set of criteria which, he claims, demonstrate limitations inherent in all KR systems to date. KODIAK, his system, focuses on the "relation" notion. However, two points should be noted. First, KODIAK opens the floodgates for a proliferation of concepts; indeed, Wilensky concedes the number of concepts will exceed that of words. Consider, for example, how the "mind" is used in this book.

This is due to its attempt at context-independent KR. Secondly, KODIAK is not really language-independent (pace, Wahlster, 1988). For example, Wilensky subsumes "owner" under "legal entity." There is no such concept in Gaelic: "sealbhdoir," the nearest analogue, cannot appropriately be used as a legal term. The highly specified nature of Wilensky's relational networks will result in many such malapproprisms. Translation requires cultural attunement. On a higher level, the notion "view" which Wilensky introduces may well be language-independent.

Wilensky (op cit) takes CD to task for its epistemological inadequacy. CD (Schank et al, 1975, 1981, 1986) is based on a minimalist interlingua (IL). Schank was greatly influenced by case grammar (Fillmore, 1968) and perhaps by Richens' work. His IL

consists of 11 verbs (e.g. move, ingest) which can affect the numerically-indexed (–10 — +10) states of health, anticipation and awareness.

This choice of primitives seems to be arbitrary, to some extent. The basic concept underlying the verbs is "trans" (movement). However, there are many verbs in every language (like *awaken, réveiller, tuer, dúisigh*) which express changes in health, anticipation and awareness.

The knowledge encoded in its pristine form (Schank, 1975) corresponds to the Piagetian sensorimotor and preoperational stages. Piaget claims that after these, there arise the concrete operations (approximately 7 – 12) and formal operations (12 onwards) stages (Piaget 1953, 1958, 1970, 1972). At the latter stage, we've seen that a system of logic is available, as well as a capacity to reason hypothetico-deductively.

Schank does not even begin to consider the questions Piaget tackles. Therefore, Schank's choice of primitives is arbitrary and his epistemology hopelessly inadequate. However, his later realism (Schank et al, 1977) allowed production of some functional systems. A final caveat must be entered because of Schank's implicit tractatus-type theory of language (Wittgenstein, 1922). Indeed, one of his core entities is the picture producer (PP), a direct evocation of early Wittgenstein. If early Wittgenstein is, in fact, incorrect, this evocation is unfortunate.

Riesbeck's request-based system (Riesbeck, 1975; Birbaum et al, op cit) uses a production system to parse. Words ("concepts") have associated test-action pairs, or requests.

As parsing proceeds, a concept list and a request list are both built up. Requests can test for the presence of lexical items or ordinary properties of the concept list. For the "concept" Fred, the test is T; the Action is Add (PP – Class (Human Name (Fred)) to C-List. Eli, the more refined of Riesbeck's parsers, has been optimized by e.g. (Gershman, 1982). It is used in most of the Schankian systems now to be described.

Cullingford's SAM (Cullingford, 1981) was a series of programs designed to understand stories. The context of the stories, not surprisingly was extremely specific e.g. diplomatic incidents. ELI was used as mentioned above, to produce a CD representation of the text. Certain invariant points of interest were expected:

1. The events.
2. The precise order of events.
3. The *dramatis personae*.

These invariants were recognized by scripts and demons (see Charniak et al, 1985). Business considerations dictated that SAM should decrease its typical run-time from sixteen minutes. Even before the arrival of the present, generation of computers, FRUMP (De Jong, 1982) took about 2.5 seconds to perform a similar job of understanding. Moreover, it produced summaries in English, French and Chinese of the input text.

FRUMP first analyzed the text to find out what kind of story was involved, then filled in the holes in the frame (see Winston, 1984) associated with that story. Typically, the stories were taken straight off the UPI newswire. At this point, Schank began to set

up Cognitive Systems, Inc, to exploit the obvious commercial potential of such systems. He later left.

Lebowitz's (1978) IPP (integrated partial parser) is a further text-understanding system which functions in much the same manner. Its major innovation is the ability to recognize types of stories seen previously. As has been mentioned, Schank's (1986a 1986b) current work extends this ability to learn from experience. He attempts to extend the understanding and creativity of such systems by refining their explanations (XPs) of new phenomena. Since his resignations from Yale and Cognitive Systems inc, he seems more interested in education than NLp.

Lehnert's QUALM (Lehnert, 1982) cleared the ground for Schank's later analysis of XPs. ELI is again used to produce a CD net of the question. This CD net is then placed into one of the 13 conceptual categories which Lehnert herself devised. (Three such are causal antecedent, goal orientation and request). Inferences now further constrain the question specification. The resulting structure can interrogate any story with a representation in scripts or plans. Scanning mechanisms can derive the correct information. Wilks (1976a, 1983) has also produced some parsers based on purely semantic analysis. The general method is to map from semantic templates to a pre-segmented input text (Wilks, 1976). The templates are then used e.g. for English-French translation.

Two of the problems Wilks faced were AI standards. The first is the problem of disambiguating the word "pen" where the context seems equally to suggest "writing instrument" and "playpen." The second is the one to many problem in translation. For example, the French "*de*" may mean "of" (*le livre de Jean*) or "from" (*il le jete de la fenêtre*).

3.7.1.7 Pattern-matching

Techniques which match patterns in the input text to stored templates in order to build the requisite representations of the input come easily to the mind of computer scientists when faced with NLP. Thus, Weaver (1955), it has been seen, speculated that even context could be determined by "statistical semantics." Only with 1980s skepticism (and computing power) did statistical methods make a comeback.

Early English-Russian translation work used pattern-matching with rudimentary syntax (Charniak et al, 1985). The output texts were massively ambiguous (Pierce, 1966). Reasons that suggest themselves include the poor syntactic coverage (once the sublanguage had been left) and disambiguation, both of referents and word-senses. However, in a sublanguage, syntactic constructions tend toward relative uniformity (Grishman et al, 1986); anaphoric reference is a great deal of the time to the last object, even in the general, non-sublanguage case. Moreover, we have seen that gendered languages afford more scope for anaphoric disambiguation. Finally, Wittgenstein (1967) indicates that word-sense ambiguity occurs particularly when the word is outside its native language-game.

In introducing his request-based parser, Riesbeck (1975) stresses that one should not rule out use of pattern-matching. Indeed, request-based and word-expert parsing

(Small, 1982) also require prior definition of words, much like keyword parsing. Pattern-matching methods have a healthy robustness.

However, pattern-matching fails for complex questions e.g.

Wie weit ist es vo (r) (n) (Object 1) zu (r) (m) (Object 2)?
How far is (Object 1) from (Object 2)?

For this type, we need a semantic grammar. A variety of Ockham's razor holds in NLP: never use an inappropriately complex method! With that, we'll end our survey of the field.

Computational Linguistics (CL) has been extremely useful in its highlighting of issues like this. Through CL, linguists have been forced not only to give tractable accounts of their theories, but also to introduce computational rigor at points where it might otherwise have been lacking. The result has been salutary for everybody involved.

3.7.2 Philosophy of Language (reprise)

We introduced the major questions about language and knowledge in chapter 1.Some issues about the role of myth in personal development were introduced in chapter 2.

We shall use a further argument from Jeremy Campbell (1982) to close this section. He argues that myths, legends etc can potentially be understood by computers. This flies in the face of any sensible conception of myth. Consider the following classic Irish legend from the Fianna cycle:

Fionn, the leader of the Fianna, and Diarmuid, his protege, are both in love with Grainne. Diarmuid elopes with Grainne to the wilderness. While Fionn is giving chase to Diarmuid, a wild boar severely injures the latter. Fionn has healing powers, and need only sprinkle water on Diarmuid to cure him. Instead, he spills the water on the ground.

Let us now consider a CD representation of the main points of this story.

1. Diarmuid D-Prox Grainne

2. Fionn D-Prox Grainne

3. Action: PTRANS
   Actor: Diarmuid
   Object: Grainne
   To: Wilderness
   From: Fionn

4. Action: Throw
   Actor: Boar
   Object: Boar
   To: Diarmuid
   From: Boar Health (Diarmuid) = –8

5. Action:	PTRANS	
Actor:	Fionn	
Object:	Water	
To:	Ground	
From:	Fionn	Health (Diarmuid) = –10

Diarmuid, as you may have guessed, is now dead.

Understanding, Pitrat (1988) argues, is achieved when the program "has made a representation which does not depend on any natural language." CD form fulfills this requirement. The story of Diarmuid and Grainne fits into a general category of "love-magic and forest themes" (Joseph Campbell, 1968-no relation to the other Campbell) whose antiquity "goes back far beyond Celtic times." It is an archetypal tale of love and jealousy.

Were a programme to be supplied with a Piagetian scheme for the above structure, could it be said to understand such stories? Joseph Campbell would think not. For him, myth's functions include "the shaping of the individual… to his social group" as well as fostering "the centering and unfolding of the individual" in accord with both his natural and social environments.

We have now left that realm of discourse in which an unembodied representation could be said to constitute understanding. True comprehension of myth requires not only a model of the world, but participation and growth in the world. Campbell is obliquely reiterating the Dreyfus' (1986) argument that the central difference between natural and artificial intelligence lies in the relation of reality to model thereof. Bateson (1979), who we discuss in chapter 5, would agree, insisting that a story is above all a "pattern of relatedness" of the reader to his environment. This relationship is immediate and cannot be achieved by a model.

Like parsing in the CL tradition, literary criticism analyses texts to derive representations. However, the representations so derived are by no means as clear-cut as data-base calls or CD nets. For example, Anthony Burgess (1989) may say of Waugh's *Brideshead Revisited*: "It is a work of propaganda for the Catholic cause… here everything is almost cabalistically predestined… God wins… God has to win."

Donoghue's (1986) analysis of the language of Joyce's *Ulysses* and *Finnegan's Wake* give some indication of how far CL is from literary understanding. The ground shifts beneath our feet immediately: "to Joyce, language always seems to offer itself as a counter-truth to the truth of reality" (ibid). We are no longer even interested in representation, so what exactly is happening? Since "language is not responsive to transitions" a new technique must be developed to model the non-discrete nature of reality.

In *Finnegan's Wake*, "the words are confounded by taking to themselves diverse linguistic affiliations and echoes from 50 or 60 languages." The difficulty of parsing such text is a point that need not be labored.

A more general point about any literary analysis is that the representations produced are of the type that programs cannot even potentially understand, i.e. those that refer directly to the embodied reader's relationship with their social and natural

environments. It is possible, however, that some hermeneutics techniques such as deconstruction (Donoghue, 1986) may at some stage prove useful to CL. Above all, the emphasis in literary criticism on determining the context in which the writer is working in order to fully determine meaning is instructive.

In summary, then, the foregoing discussion indicates that there is no possibility whatever of a general computationally tractable formalization of language. CL should use a great variety of techniques, not just computationally convenient algorithms with a mathematical excuse. Rather, NLP can be done only within specific contexts. When semantic techniques are used, as Pitrat (1988) points out, the primitives chosen will include many applicable only to this particular language-game.

3.7.3 Theory of linguistic computation

Thompson (1983) reserves this term to describe "the communicative process in the abstract." Two questions arise naturally in this context. The first is how to formalize the expectation-driven nature of human language processing. The second relates to the interleaving, or otherwise, of syntactic and semantic processing and we've laid this particular bogeyman to rest in the general linguistic context. Let's look at it in CL.

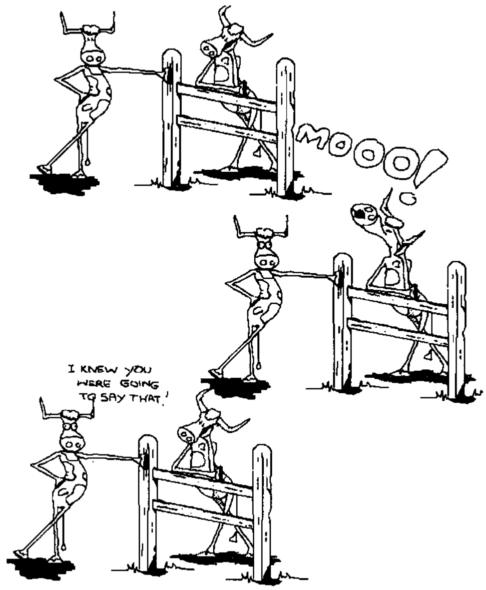
Even the origins of the use of the word "semantics" are shrouded in mystery (Tamba, 1988). It is generally credited as Breal's (1897) innovation. It can refer to properties of words which e.g. preclude ideas dreaming. Smith et al (1979) point out that the logical entailments of a sentence can be divided between those that are justified, semantically and pragmatically, and those which are in fact extra-linguistic.

That human cognition is in general massively hypothesis and expectation-driven has become clear to researchers in CL (apologies for diagram 3.13!) psychology (Shotter, 1975) and even management theory (Moynihan, 1974). Schank and Riesbeck (Schank, ibid) have demonstrated that much linguistic performance, in particular lexical disambiguation, can be modelled as the filling by later words of the roles suggested by the requests from previous words. Kelly's construct theory (Kelly, 1955) insists that people always actively "construe" their situation. Finally, the managerial theory of cues proposes that people normally line up several hypotheses simultaneously; the one actually chosen is that for which there exists the most statistical evidence.

In this same vein, Halliday (1975) points out that language-learning for children is a fortiori a voluntary activity: it is "learning how to mean." Previous structural descriptions of the process are inadequate. Halliday's description takes a functionalist view, and insists on taking into account how the child actively tries to participate in the system of shared meanings in their society.

Both Lesmo et al (1985) and Lytinen (1986a) have addressed the issue within the framework of CL. Both point out that parsing can be greatly speeded up by judicious interleaving of syntactic and semantic components. An example is prepositional phrase attachment.

In the sentence "He saw the lake with a telescope," the attachment of "with a telescope" can be either to "He" or "the lake" on a purely syntactic parse. It is the semantic component of the system which can decide that it should normally be to



Language comprehension is massively hypothesis-driven!

Figure 3.13

"He." This is a simple example, and the increase in efficiency gained by interleaving can be great for complex sentences.

Lytinen (1986a) agrees with interleaving in this manner, and adds that the use of non-local syntactic checks is also helpful. This seems to the author a more sensible proposal either than Wilks et al's (1983) desire to totally eliminate any independent syntactic component, or Marcus's (1980) attempt to parse purely syntactically.

Yet there seem also to exist cases where the syntactic analysis is implicit, if it in fact occurs at all. Consider Wittgenstein's laborer shouting "Slab!" instead of "Give me a slab!" It seems that here the missing words and syntactic construction are supplied by the context. Moreover, agrammatical strings can yet yield meaning. One such ("hotel arson explosion") is a near-classic in CL literature.

However, the situation is more complex than that. If the NLP task is that of understanding an extended text, two cognitive acts come into play.

The first act is the act of domain-determination. The knowledge brought to bear in this first act is essentially word-meaning (Walker et al, 1986) and syntax. No operational knowledge (see 1.3.1) of the type modelled by Schank's (1982) "scripts" is yet used.

The author argues that syntax is more pre-dominant at this stage than later on in the act of comprehension. Once context has been determined, operational knowledge comes into play. Moreover, syntax and semantics interact in the manner described in Lytinen (1986a).

We've seen that the situation can be more complicated still. Wittgenstein's laborer utters only a single word: we assent when, in Tolstoy's *Anna Karenina*, a marriage proposal is successfully carried through using only the initial letter of each word.

Let us retrace our steps. The author argues that, in reading any text, a two-stage comprehension process is evident. The first stage involves domain-determination. In this stage, syntax and isolated word-meanings, are paramount. In the second stage, once the domain is determined, the interaction between syntax and semantics becomes a great deal more systematic. Lytinen (1986a) gives a good description of their interaction in the second stage.

Yet that is not quite the full story. Agrammatical strings of words can evoke full acts of comprehension. Context can be so restricted that single letters can suggest whole words (the *Anna Karenina* proposal scene). Moreover, the interaction of syntax and semantics seems quite different in the first stage of comprehension to their interaction in the second stage. We discussed this point in a broader sense earlier in the chapter; we do so now within CL.

Finally, when context is considerably restricted, syntactic processing may seem at best implicit.

The author intends to give an outline for a preliminary explanation of these phenomena. First of all, however, let's look at one final relevant set of findings.

McClelland et al (1986) describe a connectionist structure for language (see chapter 4) in which inhibitory and excitatory connections exist between elements of language. These elements can range from orientations of letters to single words. It is claimed in this approach that reading-behaviour can usefully be considered as the attempt to find statistical evidence for a particular word. Look at diagram 3.14 of Myles as Hercules: certain readings are being suppressed, others facilitated. As Myles reads, he processes "the bee's knees," not its competitors, "the cat's pajamas" and "the dog's dinner."

In fact, what we need to reconsider at this point is: how many levels of language are there? The conventional account (Jackendoff, 1987) would depict four, as in diagram 3.15. However, our current analysis would suggest at least eight, as in diagram 3.16, for written language with a correspondingly complex layered system for spoken language.

It is this author's opinion that McClelland et al's (1986) approach is essentially correct, and can fruitfully be extended. Human processing of language, the author wishes to argue, can be considered as above all the attempt to find statistical evidence for a particular interpretation of text. The evidence may come from any several or all of semantic, syntactic, phonetic, pragmatic, orthographic or operational (see 1.3.1 below) sources. The interpretation may be a Piagetian scheme, a Schankian script, or a requested piece of information represented by a single word.

The two major issues dealt with in this section are the expectation-driven nature of human language processing, and the relationship of syntax and semantics in such processing. The author believes that as the expectations vary in nature, so does the relationship of syntax and semantics. It is now time to look again at the overall model that the author wishes to propose.

From McClelland, it adopts the notion that language processing involves the collection of statistical evidence for a particular interpretation. However, McClelland et al's (1986) work doesn't venture outside the purely lexical area. The model here claims that the network also includes schemes, syntax, semantics etc. The final interpretation may be choice of one scheme over several others just as easily as choice of one word over its rivals.

The precise weighting of the evidence from syntactic, semantic, lexical, orthographic and operational sources depends, inter alia, on the degree of restriction of context. Lytinen (1986a) takes for his corpora grammatically correct and literate sentences. However, let's again mention "ILY" in a marriage-proposal scene. Alternatively, try "lecture student confusion question." It is obvious that in, for example, the emotional

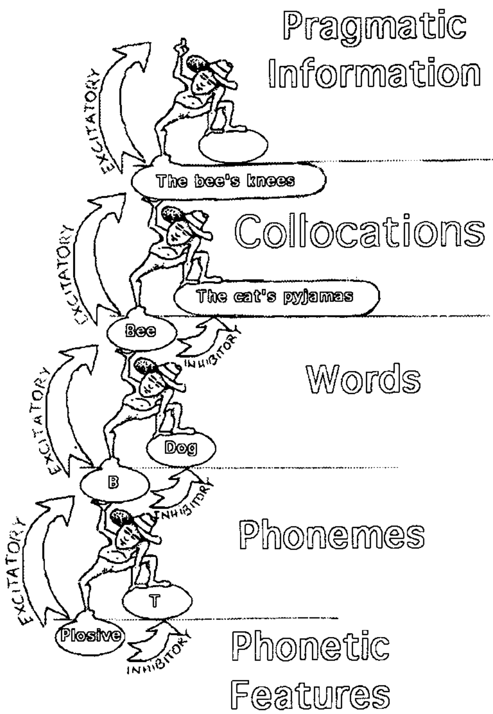


Figure 3.14

nexus of a marriage-proposal scene, a single phoneme can trigger a whole script. Syntax, if used, is very much implicit here.

Syntax deals with the regular combination of words. There is some evidence (Campbell, 1982; Johnson-Laird, 1988) it is a manifestation of a more general underlying cognitive ability. The author wishes to claim that its importance in language-processing, and its interplay with semantics, both depend on to what extent context has been restricted. When, in stage one of language comprehension, context is relatively unrestricted, syntactic knowledge is paramount. However, in stage two, context may be so restricted that syntax is at best implicit.

The model offered here explains a range of phenomena. On the one hand, it is no longer a surprise that agrammatical strings can yield meaning, and that, at one extreme, a single phoneme can activate a script. On the other, the varying degrees of interaction between knowledge from syntactic and semantic sources are now explicable.

The model is tentative, and much work remains to be done. McClelland et al (1986) report evidence for their theory. They found psychological subjects could more easily find "k" in a word (e.g. ankle) than in a meaningless sequence of letters. Thus, they claimed, the notion of excitatory links between letters and words in an hypothesized neural network gains support. The author envisages research which examines how subjects differentiate between word-senses on the basis of different underlying scripts, and guess at the identity of acoustically under-determined phonemes on the same basis, inter alia.

The consequence for ACL is, above all, a justification of the use of a variety of techniques. If the context has not yet been determined, word-meaning or keyword analysis is necessary (Walker et al, 1986; De Jong, 1982). For a relatively restricted context, the relationship between syntax and semantics seems well-handled by (Lytinen, 1986a). At a further point of restriction, minimalist interlingua systems (Schank, 1975) and template-matching (Weizenbaum, 1976) seem to work.

Thompson's (op cit) setting aside of "theory of linguistic computation" for the study of the "communicative process in the abstract" makes it relevant to consider non-verbal communication here. Along with unrestricted speech processing and textual comprehension, Wahlster (1986) puts human communicative competence on the

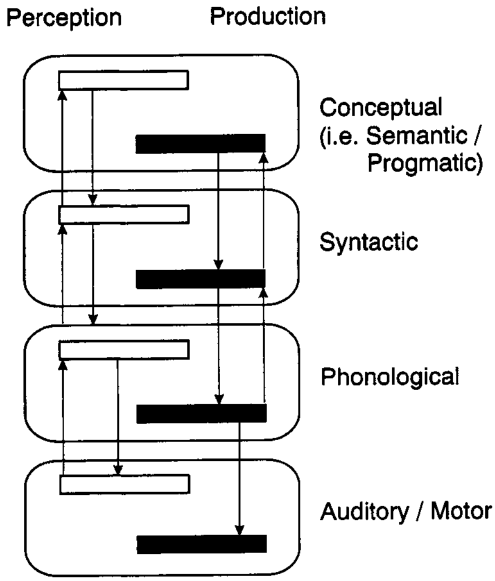


Figure 3.15

pantheon of goals unattainable in CL. Human communicative functioning is we have seen, expectation-driven, and the minuscule channel capacity (Miller, 1968 puts it at 25 bits per second) is compensated for by massive parallelism.

When is NL more appropriate than Mice, Icons etc (WIMPS) for non-machine interaction? Some researchers have reviewed work on interface design, but in a specifically psychological framework. (Rules proposed include a restriction on spoken output to a maximum of five seconds). Bates (1984) tackles the problem head on. NL communication is more appropriate, he argues, when the following considerations are paramount:

1. The task is relatively undefined.
2. There are no clear indications as to the limits of the system.
3. The existing interface is pitched at too high a level for the actual users.

Woods (1984) outlines a system combining NL and pointing for large, multivariate tasks like (Woods' scenario) World War 3.

Unless at least some of considerations 1_3 are relevant, computational linguists can, depending on their original background, return to teaching French or Cobol programming, as soon as the EU and other funders of MT programs cease laying golden eggs. WIMPS may possibly eliminate 2_3 for interface work; the critical issue is 1.

In summary, then, Thompson's insistence that the "milenniar" parser should be massively expectation-based is correct, as is his claim that the field of NLP has yet to address this requirement.

3.7.4 Cognitive Psychology and Computational Linguistics

It will be remembered that the model advanced above distinguished between two stages of language processing which differed with respect to the presence of operational knolwledge only in the second. Let's now recap Piaget.

Piaget, we've seen, insists that knowledge is formed by interactions between the subject and object which define the limits of both. (Piaget, 1926, 1970). The resulting knowledge has active elements called schemes (Schank et al's (1975) "scripts" are a rough analogue), and static, representational elements called "schemas." For Piaget, it is incorrect to suggest, as Wittgenstein (1967) does, in his refutation of private

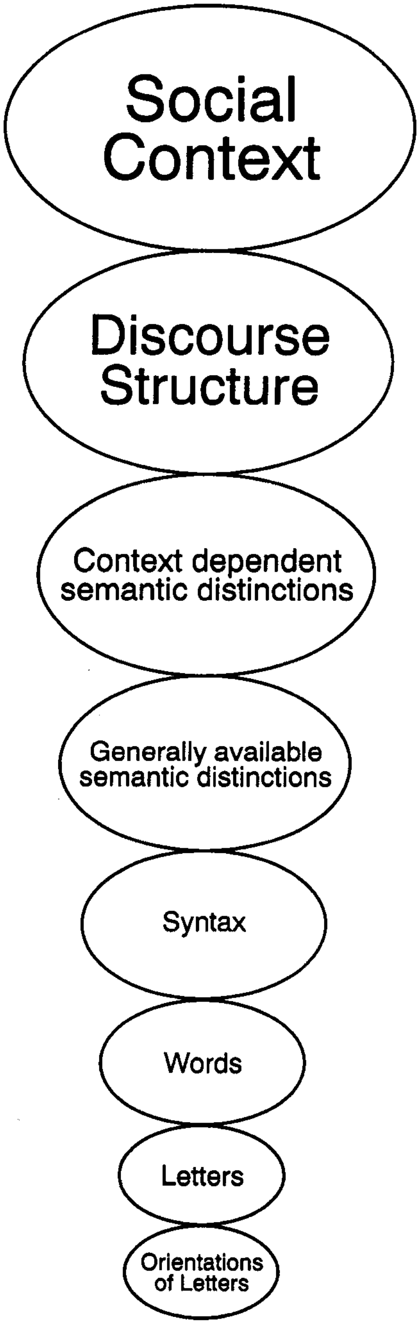


Figure 3.16

languages, that knowledge can be gained only by the process of mapping private sensations onto words.

The ontogenesis of language, Piaget claims, is a subset of the more general process of the ontogenesis of thought. This relation of set to subset is valid even for syntax (Piaget, 1926); the child can master relative clauses only with mastery of the more general motor operation of insertion, according to Piaget.

In Piagetian genetic epistemology, as we saw in chapter 2, there are four stages through which humans must progress to arrive at adult logical competence. With the advent of each new stage, the individual's mode of apprehension changes.

At the opposite extreme to Piaget, we found the Sapir-Whorf hypothesis (Vygotsky, 1962). For Whorf, our conceptual apparatus is limited absolutely by the distinctions suggested by our language. However, we've seen that this hypothesis is simply not tenable, given the evidence against it from child development.

Piaget insists that knowledge is the result of interactions midway between subject and object (Piaget, 1971, 1972). He insists, moreover, that private languages (in the sense of representational schemes and schemas), can exist, and are referential because their origin is through these kinds of interactions, not idiosyncratic, non-referential mental process. Piaget will also allow logical atoms, of a sort. However, they will resemble the ultimate thought-elements of the *Tractatus* (Wittgenstein, 1922) only after infancy. In infancy, they will resemble more sucking reflexes, etc..

It is at this point that developmental psycholinguistics, in general, and the

work of Vygotsky (1962), in particular, we saw become relevant. With Vygotsky, we've seen claims that "language" and "thought" (Piaget's "operational knowledge") have distinct evolutionary roots. Birdsong, for Vygotsky, is non-conceptual "language"; rats' maze-solving is non-linguistic "thought." Only in human children after infancy, he claims, does "language" become conceptual and "thought" acquire linguistic expression.

Consequently the existence of a two-stage process in language comprehension makes more sense. It is only in the second phase that operational knowledge features. Thus, the success of Schank's later script-based systems (Schank et al, 1977; De Jong, 1982) now seems explicable. In them, the context is chosen, then a script representing the relevant operational knowledge is applied.

Wittgenstein was correct to renounce his earlier (1922) contention that there is a context-general calculus which can relate language to the world (or to "authentic" (in Heidegger's sense – Passmore, 1966) schemes or scripts). The relationship between knowledge structures like scripts and the relevant linguistic expression thereof varies between context. The underlying operational knowledge may be as different for two words as a screwdriver is from a hammer.

Let us again take stock. The author believes that the arguments of the later Wittgenstein (1967) need to be answered, and has chosen this ground (ie cognitive psychology) in which to answer them.

Piaget (1926, 1971, 1972) provides us with counter-arguments, but burdens us with the task of fitting operational knowledge into the system. The author considers that one can so fit it in the notion of "context." Also, Piaget's over-emphasis on the operational at the expense of the linguistic needs to be tempered by findings from developmental psycholinguistics. Finally, it should be emphasized that the relationship between knowledge structures and linguistic expression varies between contexts.

To write a successful CL knowledge-based system for a given application is to specify that relation for the particular context. Schank's most successful systems grew from this realization. After earlier attempts in micro-contexts with a minimalist interlingua, (Schank et al, 1977) declined to separate "form from content." For each application, each context, the rules of relation of operational and linguistic knowledge had to be re-drawn. This makes the development of knowledge-based ACL systems the extremely difficult but not impossible task that it is.

For the next two sections dealing with psychology and CL, there are mainly disparate findings to report. They both await much more research activity.

3.7.4.1 Computational Psycholinguistics

The Chairman of Coling 88, deplored the lack of research in this area, citing only Kaplan as a non-closet computational psycholinguist. Kaplan and colleagues explored garden paths in relative clauses. Miller (1968) whose work focused on the psychology of communication which is cited above in the section which deals with the theory of linguistic computation, suggests in a finding with which the reader may now agree that human language processing becomes difficult after the fourth relative clause. Kaplan's earlier work (Kaplan et al, 1971), focused on developmental psycholinguistics.

It has been suggested from time to time that machines could learn in analogous fashion to children, but little progress has been made.

Johnson-Laird (1983) adduces findings due to Marslen-Wilson that show the simple presentation of a word activates it in all the possible contexts in which it might appear. This author insists that resolution of the exact meaning of the word awaits further evidence from the input text. We now have an analogue in NLP to Sperling's work on iconic imagery.

Finally, Thompson (op cit) insists on the relevance for this area of putting the world in the machine. Much work remains to be done on precisely what kind of hypotheses the human language understander lines up, what kind of evidence is sufficient to resolve the issue, etc.

3.7.5 The Active NLP movement

It is a consensus that NLP, considered as the general task of analyzing an arbitrary text in order to derive output for arbitrary ends (be they translation, data base interface or whatever) is extremely difficult. Wittgenstein's major achievement might be said to be proving that it is impossible. One way to ground the area is analogous to that taken by the active vision movement. This program redefined computer vision studies as task-oriented from their original definition in terms of producing a 2-D representation of a static external world. Active NLP looks at language as it is used in the context of real tasks, rather like Wittgensteinian language-games. Inevitably, the degree of restriction of context will often resemble that in sublanguages.

The integration of natural language and vision is a case in point. Systems are included which, like ours (Ó Nualláin et al, 1994a, 1994b; Smith et al, 1996; Kelleher et al, 2000) attempt to construct arbitrary scenes on the basis of NL descriptions or, inter alia, attempt an interlingual representation of spatial descriptions or visualize the primitives used in KR formalisms like CD. Dialogue in this new area has proven hard to establish between the different practitioners.

The task for the computer in our system consists of the incremental interpretation and reconstruction of verbal scene descriptions as they are spoken (or initially, typed) by a human user. The idea is to allow a person to give a very sparse description of an environment that he wishes to create a model of, and to have the computer system instantiate and display an almost photo-realistic, three-dimensional model that is consistent with everything the user has said so far, and whose additional details are in some sense typical for the domain. As the user's description proceeds, some of the details and parameters of objects in the scene that will have initially been given default or randomized values will change to the specific values mentioned by the user. New objects can be introduced into the scene by simply mentioning that they are there, and these new objects too will initially appear in canonical orientations, in "reasonable" places, and with sizes, colors and other attributes taking on values that are randomly distributed around appropriate norms. The defaults will often of course be inappropriate to the model that the human user has in mind, but as they continue to specify salient details of their own view of the world, the computer's internal model (and the screen view) change correspondingly, and new subsidiary defaults come into

play. Of course, most of the detail is registered subsidiarily (in Polanyi's sense, 1958, chapter 4) if at all.

A user's description of a scene might proceed as follows. The visualization window on the screen is initially black, and the system waits for the user to begin.

User: "You are standing on a suburban street corner''

(immediately a scene appears, consisting of typical suburban houses with lawns, sidewalks along the edge of the street, trees etc.)

User: "The house on the corner has a red door, with green trim around the windows''

(scene adjusts to fit the new descriptive detail. Note the phrase "on the… corner'' occurs again, with a different interpretation because the dominating node is a house rather than a person.)

User: "Walk down the street to your left, which is Rowan Crescent. "

(a street sign appears, with the new name on it, and the scene changes to reflect movement of the observer. The database is incrementally instantiated to include additional detail required to fill in the scene. The compass-point orientation of streets is still undetermined.)

Implementation of the system is not yet complete, but we had a version running on a Sun workstation that supports dialogues similar to those shown. We used the Alvey Natural Language Tools grammar and parser (Grover et al, 1993) for syntactic and semantic analysis of the English input; we built the domain models and translation mechanisms in CLOS (the common lisp object system); and the graphical visualization facility was originally implemented directly in Common Lisp with some use of CLOS as well. We then moved that final component to XGL. In 1998, we wrote a whole new system at Nous Research. After deciding on a multi-user web-based application, we experimented with VRML before moving to open GL. The NLP is now handled in a mixture of Prolog and Javacc.

The system investigates several different themes. One is the postulated common semantics (in the "model" sense above) of language and vision as a "language of thought" mechanism for grounding. The data we have so far from our project establishes a set of relationships between the logical form expressions produced by ANLT and the naive physics of the streets and blocks worlds. We believe that we shall have to experiment not just with different domains of application, but also with different semantic formalisms in order to derive principles of relation. The isolation of these principles is important enough to justify the effort.

Another is the active NLP theme of assessing how far NLP can be taken in a computational environment and the investigation of the limits of that environment. We

have prepared well with respect to the tools used and task chosen; undoubtedly, however, we shall come across some limitations to our approach.

3.8 Language and other symbol systems

Let's note the following facts about language once again:

1. All natural languages are within certain precise limits of formal complexity.
2. All natural languages (NLs) can in some sense be described in formal grammars.
3. All NLs have a recursive structure: for example, we find a sentence embedded within a sentence in an utterance like "(He said) that (He was going)."

For NL, substitute "music," and these statements seem also true. It will be argued in chapter 7 that the same state of affairs could well hold for vision also. The CSNLP conference in 1999 investigated these themes: Mc Kevitt et al, 2001 is the result.

3.9 On the notion of context

Two extremely evident trends within CS are of relevance here. The first is the recent emphasis on situated cognition à la Brooks (1991): the second is the acknowledgement from such as Slezak (1993) that context is not just another entity (along with, for example information capacity) that can be introduced, as if from outside, in order to explain behaviour. On the contrary: we are embedded in contexts continually, and it is in fact entities like "language" which, considered in the abstract apart from their actual use, are misleading. One of the concerns of this chapter has been to acknowledge the truth of these two ideas in an overall theory of language-processing.

In this chapter, we have strongly distinguished between two types of cognitive act: that of context-determination and that of processing within a context. Only the latter process features operational knowledge. We can usefully refine our vocabulary here: it is better to call the initial act domain-determination, and acts which further restrict the discourse content can be termed acts of context-restriction. These acts cause the levels of language to collapse in a manner which allows, for example, direct interaction between the pragmatic and syntactic levels. It is this type of interaction which must be examined by theories of situated cognition, which are by definition theories of the effects of context.

A final speculation: we spent a long time, while clearing the ground, examining the relationship of syntax and semantics. Syntactic relations, we argued, give semantic relations in a sufficiently restricted context. Yet there undoubtedly are occasions where a neat semantic theory of a domain exists: for example, the theory called model-theoretic semantics is trivially true if we are talking about set theory. We are now right back to the position we advanced in chapter 1 that different types of objectivity exist, all valid for their own types of application. In chapter 8 we begin to discern the cognitive role of self in our schema. So far, it is clear that context has been added to the Nolanian schema as a major player. Self will be found to be intertwined with context.

3.10 Mind in Linguistics: summary

Computation and linguistics have defined the boundaries to the discussion in this chapter. We first of all reviewed the main theories of linguistics. All seemed in some way incomplete: we noted that for Edelman the notion of formal linguistics is itself an aberration. In any case, it was established that we could not equate mind with any such formalization of whatever power. Cognition involves interactions between language and thought. We reviewed how these interactions developed both ontogenetically and phylogenetically. Having established this strand of the argument, we began to examine the relationship of syntax and semantics, as described in 3.9.. This, in turn, led us to question the conventional notions of the stratification of language as valid ideas of language processing.

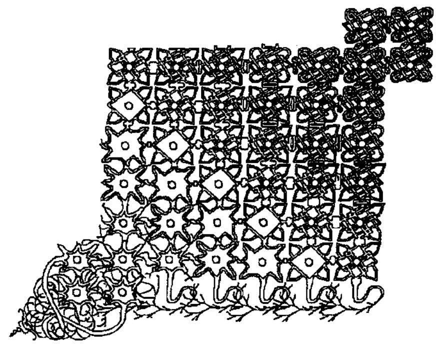
What we've been most concerned with is finding a *via media* between formalists like Chomsky and skeptics like Edelman. Our final position is that use of language involves (a) exploitation of a formal symbol system; (b) interaction of this system with operational knowledge; and (c) intersubjective knowledge of oneself as an object in the world. Neuroscientific evidence currently exists for (a) and (b). Moreover, we have found cause to greatly amplify the part played by context in linguistic behaviour.

Further Reading

Modern Linguistics by Smith et al (1979) is a good introduction to Chomsky's earlier work. *Natural Language and Computational Linguistics* by Beardon et al (1991) is well-explained and features Prolog examples. Gazdar's and Mellish's *NLP* may be available in Lisp, Prolog (the language of choice for this book) and POP-11. From philosophy, Austin (1962) has greatly influenced CL, as has Montague (1974), though the latter text is difficult. Dowty et al (1985) is a good collection on parsing, particularly in an FG framework. Finally, Kelly (1955) deals with "construal."

4. Neuroscience

The constituent disciplines of Neuroscience



The brain has been slow to give up its secrets. Like all the other areas of Cognitive Science, Neuroscience, were it truly successful, would pre-empt the necessity of separate consideration of its confrères. Had we a full neuroscientific account of cognition, the description of each of the other disciplines would be seen as subservient. For example, let's imagine that we had a full neuroscientific account of the processes implicated in Modus Ponens. We could then explain ability to perform this logical operation purely in terms of brain/nerve cells (neurons) firing. Inability to perform Modus Ponens properly in certain circumstances could, by the same token, be explained with respect to neural aberration. That description would take priority over the psychological account, which might explain performance errors in terms of attention lapses, alcohol ingestion etc. The purpose of the psychological account would simply be to translate the primary neurological account into its own terms.

Similarly, linguistics issues could be resolved with respect to the workings of a complex neurally-implemented formal system. The fundamental motive of ethnoscience would simply be an "a posteriori" rephrasal of why neural system A had different nuances to neural system B. Every sub-discipline within cognitive science aspires to be the whole of the subject. Neuroscience fails just like all the others. However, here the case is slightly more complicated. The ambitions of neuroscience are higher than those of the rest, in that it would claim to afford a description of cognition at the physical level as well as the symbolic, which none of the others care to try and do. Insofar as this is the case, the fall to earth is more precipitous: we know very little about the hardware which supports cognition after a century of modern neuroscience.

Damasio (1999, pp. 76–77) neatly summarises the current situation:

> "The current description of neurobiological phenomena is quite incomplete, any way you slice it. We have yet to resolve numerous details about the function of neurons and circuits at the molecular level; we do not yet grasp the behaviour of populations of neurons within a local brain region; and our understanding of the large-scale systems made up of multiple brain regions is also incomplete…. We have not yet fully studied either neurobiology or its related physics."

However, as he approaches the question of how we experience ourselves as the centre of a multi-modal stream of experience, an experience generated somehow in the brain, he is quite sanguine about the advances that have been made:

> "Neuroscientists have been attempting unwittingly to solve the movie-in-the-brain part of the conscious-mind problem for most of the history of the field. The endeavour of mapping the brain regions involved in constructing the movie began almost a century and a half ago, when Paul Broca and Carl Wernicke first suggested that different regions of the brain were involved in processing different aspects of language (roughly put: production and comprehension thereof respectively [present author's interpolation]) … Researchers can now directly record the activity of a single neuron or group of neurons and relate that activity to aspects of a specific mental state, such as the perception of the colour red or of a curved line" (op cit, p. 77).

As we shall see, other scientists are not so sanguine.

At this stage, Neuroscience covers a multitude of sub-disciplines within itself. Neuroanatomy deals with the gross structure of the brain. Neurophysiology deals with its physiological functioning. Cognitive neuropsychology attempts to map cognitive function onto anatomical location or, failing that, functional groups of neurons. For Kosslyn (1997, pp. 159–160):

> "Cognitive neuropsychology, at least as characterised by Caramazza, Shallice, and others, focuses on the functional level per se. They want to understand information processing independently of properties of the wetware itself."

For Kosslyn, then, cognitive neuropsychology is a functionalist enterprise; it is to be distinguished from cognitive neuroscience, the attempt to intuit how cognition arises from brain processes.

Nor is the Christian virtue of hope absent from neuroscience; a set of eliminative materialists, the neurophilosophers, await the resolution of philosophical questions, past, present and future, in the advent of neuroscience. (Now we see as through a glass darkly, then shall we see face to face.)

This chapter, on the other hand, focuses on what is currently known and what is likely to be known about neuroscience in the foreseeable future. We start off with the investigative methods of neuroscience. Until recently, much of our knowledge about neuroscience stemmed from brain injury either accidentally or deliberately inflicted.

Among the most appalling incidents in the history of science have been the experimentation conducted on "subhumans" by the Nazis and in mental hospital patients by doctors in the so-called civilized world. What makes things worse is that non-intrusive techniques are now available, and very little was found out through the other research for which "barbaric" is not nearly an adequate epithet.

We then spend some time focusing on gross neuroanatomy. It will help to briefly discuss the biological development (epigenesis) of the brain. As we discuss anatomy, we find ourselves at times forced to locate functions across gross anatomical divisions.

This forces a discussion of to what extent and which psychic functions are localized and which are globalized. Following this, we summarize our knowledge and then our ignorance.

The computational paradigm – variously called "parallel distributed processing" (PDP), "neural networks," (which don't really exist yet), and (a term also used here) "connectionism" – was originally neurologically inspired. It may yet have much to say on how symbols arise from the apparently chaotic calculations of billions of neurons. We discuss connectionism first as experimental neuroscience. We then introduce the major conceptual construct therein, the "formal neuron." This leads us to a discussion of connectionism's neurological and psychological validity. We then speak about the learning paradigms current in connectionism. One of them, competitive learning, leads us down old pathways of evolutionary theory.

A central problem remains: how do symbols arise? Alternatively: what is a symbol, that we should know it? Do we have a binary system of neural impulse and full symbol, or (the more likely conclusion) is there a continuum in existence? Another issue is the experiential correlate of "subsymbolic" PDP. Michael Polany's notion of subidiary awareness is advanced as an hypothesis here. We then discuss connectionism, per se, as a computational tool and to our surprise find the technique of Archimedes quite useful.

We then discuss the brain as a computational system. As such, it is quite different from its rivals in chapter 5, and helps proper consideration thereof. Finally, by way of tying together some of the strands of our consideration of Neuroscience, we discuss the work of Gerald Edelman.

4.1 The Methodology of Neuroscience

4.1.1 Lesioning

We've already looked at the old-fashioned way to do experimental neuroscience: select a subhuman, tie him down, and cut away that part of the brain for which one wishes to establish a function. If a particular function doesn't survive the procedure, the tendency is to localize it in the lesioned area. However, this methodology tends to have technical drawbacks together with its definite whiff of absolute moral evil. For a start, few cognitive functions are localized enough to yield to this type of investigation. Secondly, invasive neurosurgery is still an inexact science. Finally, the subhuman is likely to have averse reactions to the procedure she has had to undergo, and may be unwilling to undergo it again. Electroconvulsive therapy (ECT) has sometimes been observed to use this fact, in that chronically depressed patients will act extremely happy in order to avoid having to endure once more a large voltage being established across the space between their ears. Its origins are in the abattoir; yet it may be useful in some types of mental illness (the existence of much of which has itself credibly been doubted). The original inspiration was cows' frenzied response to receiving a blow on the head.

Two further cases in point are the "discovery" of the pleasure centers in the ungeate nucleus of the brain by an American neurosurgeon and Penfield's localization of specific memories in anatomically distinct cortical areas. A video of the American

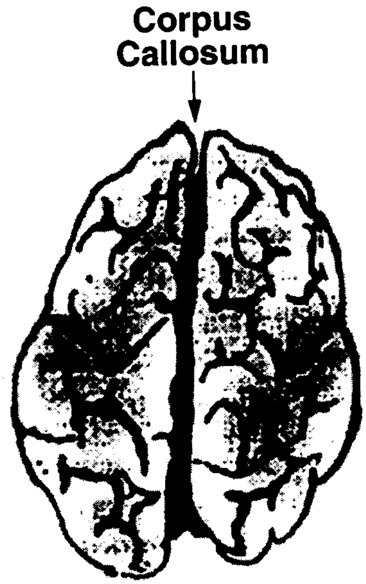


Figure 4.1

(deliberately unnamed here) smiling happily and interrogating a female subhuman still exists. The subhuman has, Skinner-style, a panel from which she can choose one of three buttons. To the neurosurgeon's pleasure, she continued to press the one which resulted in stimulation of her ungeate nucleus. She described it as the "sexy" button. His conclusion that this resulted in stimulation of a pleasure center is correct, but it was far more likely to be his than hers. Moreover, it has been known since the late 1970s (twenty-odd years after that research) that morphine-analogous hormones called the endorphins located in the nerve terminals, evoked perhaps by electrical discharge, also regulate pleasure. In like fashion, Penfield's work, which involved stimulation of cortical areas until patients found themselves remembering items as specific as sunny days beside the river, has also recently been called into question. It has never been replicated. Had Penfield's findings been corroborated, they would constitute outstanding evidence that memory is "localist," i.e. that specific memories can be very strongly associated with specific neuronal groups: the strong version of the alternative "distributed" hypothesis is that memories are spread all over the cortex.

The neuroscientific search for localization of function has also had some spectacular successes. The earliest such was Broca's (1860) implication of an area in the left hemisphere of the brain in language. If damaged, one becomes speechless (aphasic) to varying degrees: some recovery can be achieved only if the trauma occurs in infancy. Indeed, language in its two main manifestations (spoken and written) has been a happy-hunting ground for neuroscientific ambulance-chasers in that specific pathologies for complete loss of speech (aphasia), writing (agraphia), and reading (alexia) have been identified often correlated to specific neuropathology, perhaps the result of a stroke cutting off the blood flow to the area. Dyslexia, dysphasia and dysgraphia (which is commonly and wrongly called dyslexia) are milder symptoms.

Look at diagram 4.1. The brain's symmetric form requires communication between the two hemispheres through the corpus callosum. This section has no other known function than that of telephone exchange and was occasionally removed in cases of severe epilepsy. (Let's note, in passing, that the nerve fibers descending from both hemispheres cross over, resulting in the left hemisphere controlling the right side of the body, and vice versa). Broca's localization was confirmed by this procedure: an image shown only to the right hemisphere could not be verbally identified (the right

hemisphere has a very limited, often obscene vocabulary), except in the extremely rare cases where speech is located in the right hemisphere. Moreover, it does rather seem as though, in the normal case, spatial and musical reasoning are located in the right hemisphere. However, at some point in the 1960s, speculation began to go seriously off the rails. Two minds! Two consciousnesses! One version of this hypothesis casts the left hemisphere in the role of an interpreter of all experience, more or less carrying on a monologue to explain the world to itself, sometimes with destructive consequences. One such example is if the patient suffers a biochemical imbalance leading to depression; the interpreter deepens the depression by inventing a story to explain it. We should remember this quote from one of the patients used in these investigations as we discuss this issue of fragmentation of personhood in chapter 8:

> "Are you guys trying to make two people out of me? "

Typically, these unfortunates would be asked to perform separate tasks with right and left hemispheres, while perhaps also listening to a commentary on the soccer world cup in the left ear, and the US Open golf championship in the right. Most psychology textbooks include a rather benign diagram of the setup. The conclusion must be that personhood, as distinct from self, is unitary, despite terribly contrived experimental setups which would tend to fragment many people with perfectly intact corpora callosa.

Lesioning, then, has not revealed as much as one might have thought, and far less than the appalling ethical standards of many of the experiments might seem to demand as justification. The ultimate reason seems to lie in the fact that the brain does not localize function spatially as neatly as one might wish. We discuss that at length below. We also discuss later some localizations suggested by the different lobes of 4.2. For example, the occipital lobe handles visual processing.

4.1.2 Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI)

Certain isotopes of common atoms emit positrons. Oxygen-15, far less common than the O_{14} we love and breathe, can be traced after an injection into the blood stream by tomographic methods. An example application is tracing the neural activity corresponding to eye movements. The major feature to track is going to be the oxygen debit in inactive parts of the brain which don't have an appropriate blood flow. PET can be usefully supplemented by the high resolution imagery afforded by functional MRI (FMRI). Difficulties still abound. PET gives receptor pharmacology, tissue pH, glucose utilization, and oxygen consumption, inter alia. However, the data are still quite approximate; much signal-processing needs to be done. Various techniques have been developed. The first was the obvious region of interest approach, in which the brain is simply divided up into several distinct areas. This approach was too crude outside the primary sensory and motor areas. Secondly, the subtraction method "identifies those areas of the brain that differ between the task and control states" (Raichle, 1997, p. 20). More sophisticated still was the correlational approach to fmri,

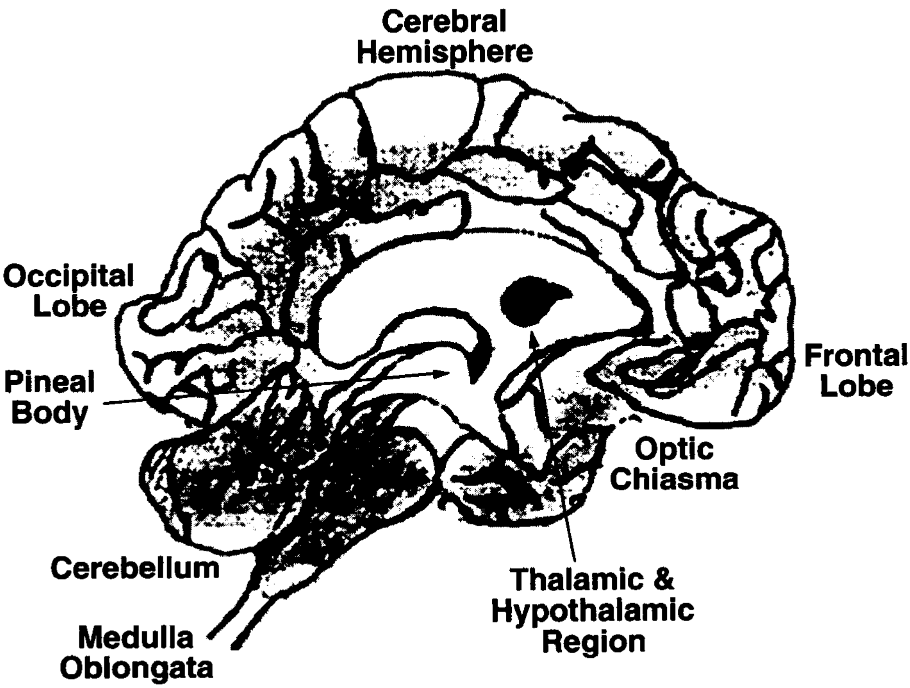


Figure 4.2

which looked for a temporal correlation between a particular input and the resulting response in the cortex. Finally, PET images were submitted to conversion to Talairach stereotaxic space, which allowed scaling of effects across different subjects. Much work remains to be done.

4.1.3 EEG

Again, a method with a past vulnerability to 1960s excesses. The electrical activity of the brain was first crudely measured at the start of the nineteenth century. About 20 years ago, it was found that experienced meditators showed ability to surges in the (alpha) brain-wave forms associated with sleep. The followers of Maharishi Mahesh Yogi, in particular, claimed scientific charter for their technique. It is not my intention to deny the beneficial effects of meditation, but the particular result quoted in the newspaper publicity of synchrony of the two has has not been replicated.

EEG can, however, particularly assist psychological experiments. Take the following list of words:

Dollar Penny Bob

For an American, the word "Bob" is likely to provoke an "anomalous" reaction, manifest in a jump in EEG activity registered. For a middle-aged Irish or British person, the registered anomaly is more likely to be "dollar"; "bob" was commonly

used for the shilling coin whose present-day equivalent is the 5p. EEG is a relatively crude technique.

4.1.4 Other techniques

It is possible to use other nonintrusive techniques for neuroscientific research. Tracers and dyes might differentially stain certain types of neurons and not others. Retroviruses are being experimented with. Magnetic systems like squids gain popularity.

In particular, the pseudo-rabies virus together with anatomical tract tracing and dies are revealing much concerning neuronal architecture and pathways. Other recent promising techniques include patch-clamp recording and intracellular monitoring. Single-neuron monitoring is of obvious intrinsic interest. Rat studies using this technique have been credited with helping sufferers of epilepsy. This technique has produced one finding of extreme interest to us (which incidentally makes Smolensky's work – see below – seem a little narrow in conception) in that neurons seem to vary greatly from simple to hypercomplex in the specificity of the information encoded.

Inevitably, the functioning of single neurons excites a lot of interest. In a classic finding, a cell in the primate cortex was found to respond only to a primate hand. This gave rise to speculation that "grandmother cells" existed i.e. cells hard-wired to respond only to that loving face (Hofstadter, 1979, pp. 345–8). This type of monitoring of single neurons may reveal much more.

4.1.5 Counting

Well, this actually hasn't been done yet. In fact, the number of neurons in the brain is variously estimated at 10 billion or 100 billion neurons, with most textbooks splitting the difference and plumbing for 50 billion. Recently, Jacob T Schwartz (1988, p. 124) upped the ante to 1,000 billion neurons. However, he was bid down by another article in the same collection (Cowan and Sharp, 1988, p. 85) which chose the miserly 10 billion figure again. Yes, it's perhaps a little premature to create a neurophilosophy without performing some arithmetic: our ignorance of the brain starts with the number of neurons, and develops from there. A word of warning: you've lost a few hundred since the start of this chapter, given that we lose thousands a day. However, they can regrow

One estimate of the number of connections (Edelman, 1992) suggests that someone counting at a rate of one connection per second would take 32 million years to complete the task. A neural section the size of a matchead contains about one billion connections: I could be bound in a nutshell, and consider myself a king of infinite space.

4.1.6 Double dissociation

This technique is strongly related to lesioning. Essentially, if a specific lesion in area A causes inability X but not inability Y, and one in area B causes only inability Y, the conclusion is that area A is correlated with ability X and B with Y. For example, if a lesion only in Broca's area causes problem in speech but no visual deficiencies and one

only in the occipital cortex causes the reverse, one tends to make the obvious attributions.

4.2 Gross Neuroanatomy

4.2.1 One brain or two?

We have already discussed the "split-brain" school which attempted to posit separate consciousnesses (in the case of Penrose, 1989) or indeed "selves" in the two hemispheres of the brain. A more useful type of division is perhaps that between the neocortex and the rest of the brain. The neocortex was formed over the past half million years in an unprecedented evolutionary explosion. (Incidentally, the speed with which human language developed indicates that it may have used pre-existing neural hardware, the type of kluge-like solution which nature has often used in the brain). It is difficult to quantify or understand the evolutionary pressures which gave rise to it. The rest of the brain is known as the limbic system and is in evolutionary terms a great deal more primitive. It is important to remember that these ancient structures survive intact in a perhaps uneasy alliance with the neocortex. As humans, we find another of Socrate's metaphors surprisingly neuroscientifically apt. He conceived the person as in a chariot driven by two winged steeds. One attempts to fly toward the heavens: the other's goal is immersion in the earth. So as proponents of this perhaps insightful dichotomous view of the brain would also claim. Janus-faced, our brains run simultaneously on codes of pure intellect and pure hormone. Thus the necessity for constructs like myth.

Transmission between neurons is achieved by substances called neurotransmitters going across the cleft between two neurons (see diagram 4.3). Normally, the cleft (synapse) yawns across the space between the dendrite of one neuron and the terminal bouton of another. Let's say that transmission is from neuron A to neuron B. We call the A side of the cleft the presynapse and the B side the postsynapse. Such membranes which have been optimized for transmission are specially thickened and have certain special receptor molecules.

Many different types of neurons and of neurotransmitters exist: it certainly does not look as if Nature chose to limit herself in any way with respect to the types of codes that the brain might use.

Approximately forty per cent of the brain's consumption of energy, (which has a similar percentage of demand on the energy of the whole body) is devoted to maintaining the electrochemical possibility of neural transmission. Neuron B is thus kept at a resting potential of –70 mV by ion pumps in which potassium plays a leading role. Electrical impulses (or action potentials) travel down the axon of A and on reaching its terminal produce a calcium influx. This influx causes the neurotransmitter to fuse with A's membrane thus releasing the chemical message (e.g. glutamate) into the cleft. This in turn bonds to a receptor molecule on B, causing an ion channel to open. The consequent ion exchange will create an action potential in B if transmission is successful, resulting in B's membrane becoming positive. It may however be the case that A is acting as an inhibitor, causing B's potential to decrease to –90mV. Finally, transmission for a particular neuron can occur a maximum of only about 200 times per

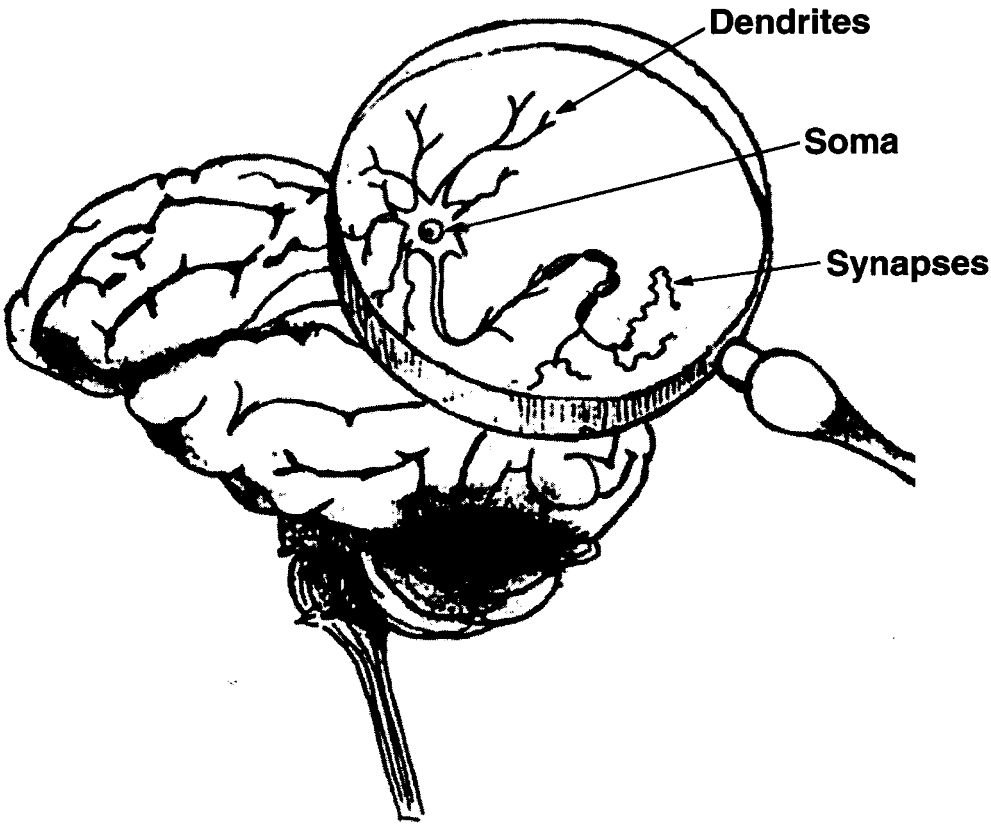


Figure 4.3

second. It will attempt to transmit the impetus to the next neuron in the sequence before settling back to its normal polarized state. With at least tens of billions of neurons in the brain, all of which can have hundreds of thousands of connections with each other, the chains of command are webs of an intricacy beyond our current comprehension (we noted in chapter 2 they seem ideal for probabilistic reasoning). This neurophysiological process is chemically mediated (mainly by Sodium) but inevitably the ion exchanges have electrical effects which are transmitted along the chain of command, activating action potentials as they go.

We have examined neural transmission in some detail for a number of reasons. The first is to compare it with transmission of purely electrical impulses in computing. There, communication is currently achieved through conventional electrical circuitry etched on semi-conductor material. The only limits applicable to computational hardware mechanisms are the speed of light, and heating effects inevitable in electrical process. Neural mechanism, on the other hand, has a limit in its speed of around 100m/s (versus around 300,000 km/s for the speed of pure electrical transmission). Yet

the programs implemented by neural systems perform tasks which are way beyond the capacities of current computation. The pattern-matching task achieved with every human glance is at least 10 years distant from current abilities of computers. The consequence is that the brain is seen to operate with a different architecture to the computer. If it is to perform tasks of such a complexity so quickly, it must have an ability to work "in parallel."

Let's explore what this means. In chapter 3, we noted that language admitted of at least these separate levels: the conceptual, the syntactic, the phonological. Each has its own laws of combination of units. Now, we can imagine that, using non-parallel "serial" architecture, the relationship between these levels is pretty clear: for example, we might assume that the conceptual level awaits input from completion of the syntactic analysis. Yet this is both linguistically and computationally absurd: many sentences admit of hundreds of different syntactic parses, and it is lunacy to conceive of these as being sequentially presented to a conceptual homunculus until he decides on the appropriate reading. Moreover, interleaving of the syntactic and conceptual analysis can cut down on the number of parses, often by a factor of hundreds. No: what must be happening neurologically is parallel processes simultaneously exploring the conceptual and syntactic levels, here making a guess based on previous experience with a similar text or utterance, there simultaneously checking the syntactic well-formedness of a chunk of the phrase with respect to that hypothesis. The processing is being done massively in parallel with regard neither for the exigencies of pure syntactic theory, nor the requirements of possible-worlds semantics: in accordance with the Principle of Rationality the brain will use whatever parsing strategy and whatever degree of parallelism are necessary to get a meaning clear enough to proceed to the next speech or other behavioural act.

Secondly, connectionism is based on an idealization of the rather rugged system used in a neural transmission called a "formal neuron." The ideas of neurons and connections are honored in this idealization: the complexities which arise from the concerted action of billions of such neurons are not. Yet connectionism has claims to neural validity of its own aside from its efficacy as a computational formalism. These claims rest on functional equivalence (see chapter 1); we're going to note that connectionist systems have memories which are more like humans than computers', and that their pattern-recognition competence has the same profile. In particular, like ourselves, connectionist (PDP) systems can perform much better if asked to complete "Shall I compare thee to a summer's day? …" than if asked, unprepared, to recite Sonnet 18 from the Master. The former process we call associative content-addressable memory (ACAM or CAAM), and the latter is look-up memory and would involve retrieving Sonnet 18 from a standard computer memory.

4.2.4 Neural epigenesis and evolution

Cells seem to specialize into organs in accordance with the instructions mediated through the fields which dominate these organs. It seems rather as if the orders which command a cell to specialize into a liver cell rather than a kidney cell are mediated through force-fields which resemble the magnetic fields necessarily generated by an

electric current. At a sufficiently early stage in embryonic development, any appropriately relocated cell will specialize, as commanded. However, at a later stage, a liver cell will refuse to become a kidney cell if transplanted.

Not everything actually is known about how learning is implemented neurally. Thousands of rats gave their lives in attempts to prove that a rich sensory environment gives rise to increased numbers of connections. In fact, connectionism is quite successful in implementing learning solely as changes in connection strength. More recent work focuses on the phenomenon just noted of cells' liability to change (transmutability). If true, it provides an extremely rich metaphor for learning and one with exciting consequences in terms of cerebral functioning. Could learning something be akin to setting up a field which appropriately alters the very nature of neurons? Alternatively, molecular modification of proteins might occur, in particular, the process called phosphorylation which modifies proteins on transmitter receptor molecules and ion channels and cell membranes. Yet another alternative is a more global process called long-term potentiation (LTP) (Fischbach, 1992) which is a long-term enhancement of synaptic transmission and currently favored as a mechanism for learning and memory in the hippocampus and other areas. It is not yet well-understood, but may be important in development. However, Gallistel (1997), to mention but one, questions LTP's credentials, and asks whether it has any plausibility as a mechanism central in memory other than its persistence.

A second striking fact about fetal/neo-natal development is the massive death of neurons which occurs shortly after birth. This, among other phenomena, has given rise to Neural Darwinist speculation about competition between neurons. This is discussed below in section 4.5. Could it be the case that groups of neurons compete between themselves for functional roles? Again we find the principle of Rationality acquiring evolutionary and neurological echoes.

Finally, let's mention the nature of the brain/body unity itself. The nervous system must be more than a crossroads for the in-coming (afferent) neural impulses carrying information about the external world, and the efferent impulses, which cause action on that world. There must be periods of quietude, switches between connective patterns: in fact, a whole patchwork of different knits (yet again!). To understand the brain/central nervous system (CNS) nexus, we must take into consideration that it functions in a living body immersed in a world with certain definite sensory qualities. Indeed, the capacity for movement itself provided many of the neural developments that give longitudinally segmented organisms an advantage over radially segmented ones such as the sea-urchin.

Again, we find it impossible coherently to discuss a system without reference to the life-world (i.e. the environment as it relates to the organism) from which it springs and without which it has no meaningful function or structure. To discern this meaning, it is necessary yet again to consider evolution over a long time-period. This biological hypothesis fits in extremely well with the situated cognition view we outlined first in chapter 1. The possibility of a biologically-based epistemology, glimpsed by Bergson and Piaget, seems increasingly indicated with our increased neurobiological

knowledge. Moreover, the purely philosophical consideration of Heidegger, and Merleau-Ponty also correctly placed us in this life-world.

4.2.5 Gross Neuroanatomy itself

We must view the brain as part of an encompassing nervous system (NS). The Central NS, rightfully considered, comprises the brain and the spinal cord. The brain, we've noted, can be subdivided into the advanced neocortex and the rest, the "limbic system." The other part of the Nervous System includes the somatic and autonomic nervous systems, used for body homeostasis, such as digestion and blood-pressure regulation.

The cortex is divided into lobes by fissures. To the front are the frontal lobe and frontal motor area. The former caters for emotional response, the latter for voluntary motor activity (later we shall consider involuntary). The fineness of the motor response required is proportional to the area of frontal lobe allotted. It is located just below the central fissure.

Sensory information is relayed to (1) the (touch) parietal lobe at the parietal lobe beyond the central fissure, (2) the temporal lobe below the lateral fissure (sound), (3) the occipital lobe. The limbic system is part of the primitive brain and is concerned with lower functions. The hypothalamus is involved with the regulation of appetitive behaviours. The reticular formation is a network of nerves running from the mid-brain to the limbic system. It monitors arousal. The Hippocampus has a vital role in STM. We've seen as well as the CNS, there is also a peripheral nervous system originating in 31 spinal and 12 pairs of cranial nerves. This can be broken down as represented above:

1. The somatic nervous system feeds to striped muscle and sensory nerves from receptors.
2. The autonomic nervous system is a motor system for smooth muscles and glands. We can consider the stress reaction as an example of its functioning.

4.3 Some relevant findings

4.3.1 Realism and Cerebral Functioning

Over the next two sections, we shall look at neuroscientific evidence for the viewpoint on cognition being promoted in this book. The first question relates to how we can justify Gibson's ecological optics and other such theories which posit a direct, anti-constructionist, view on perception. In fact, we have already encountered some of the critical concepts. First of all, we can sensibly view the competition between neurons as attempting in a Neural Darwinist way to recognize or respond to something in the external world. Secondly, and more significantly, we can coherently view the act of perception in terms of processes within the cortex synchronizing themselves over time with sensations at the sense-organs. In other words, direct non-mediated perception of the external world is possible if given time. A resonance between neural event and sensory activity can be set up. Nor need we ignore the fact that the neural activity will be a transformation of the incoming sensations: the main part, that it is a direct impression rather than a construct, remains intact.

Karl Pribram (1971) outlined a "holonomic" theory of brain function around this central idea. His earlier, more radical contentions also assumed that the brain reflected the external world analogously to how a laser does. A laser image of an object is distributed globally throughout the representation. Damage to part of the representation affects the resolution of the image which is yet wholly preserved. The early Pribram contented that neural representation was analogous and totally distributed. This view he has now modified, allowing localisms as well. In particular, he points out the analogy between Fourier transforms within receptive fields and patched holograms. One can recover the image at a lower level of resolution from patched holograms, which is one of the key points of this new analogy. The notion of synchrony between neural process and physical sensation remains intact.

4.3.2 Mylesianism and cerebral functioning

Let's now take preliminary stock of neuroscientific findings which are compatible with the ethos and specific aspects of the framework proposed in this book and in particular with Mylesianism. We needed, first of all, some neural hardware mechanisms which could support a realist epistemology and have just outlined them. Indeed, we can also define the objects of the intersubjective domain in these terms. (Can it be that our discourse about higher symbolic items has neural constraints which require that my neural events when discussing "justice" be similar to yours? Remember how we learned that concept: it took plenty of examples, followed by a person-to-person pedagogical experience with a respected elder. This is just speculation. Yet it is not, in effect, at all incompatible with Edelman's perspective described in 4.5.)

More to the point, we're espousing agnosticism on separate perceptual modules. We wish, in fact a further development, to be able to reserve the word "perception" for cognitive acts maintaining a stable relationship with an environment (and "cognition" for acts which transcend that environment) without totally losing the original meaning of the words. We wish to be able to "perceive" a mismatch between a muscular effort and a dart which misses the board (visual and somatic "perception") or indeed that Bill Clinton recovered from his Presidency's poor start by winning the NAFTA vote. The neurological evidence is on our side here: for example, as well as the role already advocated for it, the parietal lobe coordinates visual and movement information. (Likewise, the auguries from psychology are good: infants can show intermodal transfer as we described in chapter 2).

A great deal of weight falls on the shoulders of egocentric knowledge. We need it for tracking objects, for moving in any way successfully in an environment. Recent evidence (Berthoz et al, 1992) has shown that there exist neurons in the hippocampus with exquisitely directed roles. For example, some such cater for the movement of the body in particular physical contexts such as corners. This is precisely the kind of potentially nightmarishly complicated task (see the frame problem) where we need special-purpose hardware to perform the calculations unconsciously, "egocentrically." The posterior parietal cortex is another location of this hardware. Similarly, we find that tracking objects, another task where the frame problem can easily manifest itself, is

handled by the oculomotor reflex, which can if necessary also come under voluntary control. This is also a Gibsonian invariant.

The thorny problem caused by different perspectives on an object may yet be unraveled neurally as it has been mathematically. We find also that our agnosticism about monism/dualism gains greatly in strength from analysis of the neuroscientific evidence, which can be read as supporting any or no viewpoint on the issue.

4.3.3 Cerebral functioning: globalizations and localizations

It's time to put another ghost to rest. A huge literature has grown up around the issue of whether cerebral function is localized (i.e. one function per area of the brain) or global. Perhaps the high-water mark of the former school was Gall's "phrenology," where the faculties of man were assumed located to such a specific extent that one's character expressed itself as bumps in different places on the head. Psychological personality testing involved essentially running one's hand over the subject's cranium. Lashley's search for local subroutines or engrams involved teaching rats to run mazes, excising areas of the cortex, and noting the deterioration in performance. To his surprise, he found that no all-or-none relationship existed. Rather, what seemed to happen was that the deterioration in performance was directly proportional to the quantity of the cerebral area excised regardless of the particular location. Lashley was led to believe that all memories were stored globally over the entire cortex. We noted Penfield's work, which seemed to suggest the opposite, in the introductory section of this chapter.

Hubel and Wiesel (1962) won the Nobel Prize for work which again seemed to suggest localization. Only in the past few years has it been called into question. Briefly, what they seemed to have established were banks of cells in the occipital cortex of the cat, differentially attuned to lines of varied orientations. One bank would be attuned to vertical lines, another to lines at 5 degrees from the vertical, and so on. Let us conclude this discussion by emphasizing that the weight of evidence suggests both local and distributed function is used. The former is epitomized by "grandmother" cells, the latter by Lashley's (1942) brain-ablated rats. Respected researchers such as Pribram (1971) vehemently deny the existence of hypercomplex cells, let alone cells specific enough in function to merit the title of "grandmother" cells. However, Perret et al (1982) adduce evidence indicating that such exist. Indeed, the so-called "single neuron" doctrine – which has a considerable following – gives specialized cells a privileged role in perceptual processing. The conclusion, yet again, is that the brain will cohere to whatever form is necessary in order to optimize its adaptation. In another twist of the screw, it must have the capacity to give hardware support to formal systems as complex as language, music and mathematics.

One of the best-established localisms is topographic maps of incoming sensory transductions of energy. Essentially, what this implies is that two incoming stimuli of similar energy profile should eventually stimulate adjoining areas of cortex: two mutually distant stimuli should, contrariwise, activate mutually remote regions of the lobe devoted to the relevant sensory information. By this token, orange and red should be mapped onto adjoining areas of cortex, distant from violet. One exception to this

general rule seems to be olfaction, where calculations of the particular smell seems to follow neo-connectionist (PDP) formal neural principles rather than topographic principles.

Whatever the specifics of the principles, there is little doubt that the brain performs many of its calculations informed by spatial representations over groups of neurons. The cortex can be viewed as sheets (lamina) of neurons, piled one over the other. Let's focus for a moment on the parietal lobe, where fusion of information from visual and movement sources has to occur. The activations of neurons over a given Cartesian space might represent the act of throwing a dart, or reaching for an object. It seems plausible indeed that the brain has optimized algorithms for coordinate transformation over that space in order precisely to calculate the trajectory of an arm. Such algorithms may also calculate items as disparate as which particular type of carpet one is feeling, or which particular note one is playing on an instrument.

Probabilistic reasoning plays a massive role in being-in-the-world. We don't passively receive the world: we actively form hypotheses to construe it, and do this continually in every sensory modality and symbolic system. Moreover, our guesses are to different extents confirmed or not from moment to moment. You didn't expect to find Louis Armstrong mentioned in this sentence. We need to be able to maintain the integrity of our guesses in the face of incomplete and sometimes of contradictory information. A three-wheeled car is still a car. Best guesses are confirmed or not probabilistically, allowing us the kind of ability to function in the real world which AI systems still so markedly lack.

Moreover, these guesses have massive neural support. If one analyses a sensory modality such as vision with respect to the neural support, it turns out that the vast majority of the hardware involved is carrying (top-down) information about the hypotheses being lined up. The bottom-up information concerning the sensory information itself is viewed only through the context supplied by top-down information.

Our ignorance of how the brain supports higher-level cognition is impressive. It is possible that the kind of state-space transformations we have discussed above are used for much cerebral process. In this framework, phonetic discrimination, to take but one example, is achieved by laminar decomposition of the language's phonology and calculation over a 3-D Cartesian space. Those who believe that the brain is an extremely complex structure with simple principles of operation (e.g. Churchland, 1988) will hold this to be true. However, it's also possible that the brain is capable of a multiplicity of different modes of operation, implemented over qualitatively different structures. Much of the exciting research on that area comes from PDP. Let's pay it a visit.

4.4 Connectionism (PDP)

Look again at the cover page of this chapter. The Celtic design is actually a single line folding over itself, intertwining with offshoots of itself which yet now are perceived as other. See how the neural pattern becomes a pattern from the Book of Kells…. The emergence of symbols from neural activation is infinitely more mysterious than this.

We have learned little about it from conventional neuroscience and should be grateful for clues from any other source. One of the main justifications for PDP research has been its sustained assault on this question. Consequently, our discussion of PDP will first focus on its role as experimental neuroscience.

We begin by briefly discussing its central theoretical construct, the formal neuron. Of more interest to us in this section, however, are PDPs claims for psychological and neurophysiological validity. These claims are quite considerable in the former case but are not without their critics. In the latter case, there obviously is an enormous difference in scale between any PDP system attempted to date and the human brain. However, the performance differences due to lesions are impressively similar. Moreover, the neural Darwinist notion we explored in the previous section has a neat PDP correlate in the notion of "competitive learning." We must then return to our central theme, the emergence of symbols from the concerted activity of groups of neurons, and here we find surprising results. The bridge to considering PDP as Computer Science is glimpsed as we briefly consider methodological issues and the relationship to Gibson's work.

As an interlude before entering into the computational domain which extends also over the whole of chapter 5, we attempt to map PDP considerations onto conscious experience. If indeed PDP is more than a metaphor for neurophysiological process, what are its experiential aspects? What is the relation between massively parallel neural function and subjectivity? We find a surprising analogy in Michael Polanyi's work on tacit versus explicit knowing, experienced respectively as subsidiary versus focal awareness.

This brings us to one of the major new computational paradigms of the past decade: PDP as computer science. As a cognitive science (CS) paradigm, it has become so powerful that CS is often identified in terms of "Oh yeah…. Neural networks." Its power is such that biologists and physicists have joined psychologists and linguists, together with other cognitive scientists, in exploring the ramifications of PDP. As neurobiology, PDP has an obvious attraction. As physics, the thrill is more subtle, yet deeper: it has been found that knowledge can be viewed in this paradigm as particular configurations of an "energy landscape." Moreover, learning can be usefully described in the thermodynamic terms of a ferromagnetic core seeking a stable configuration. The process of learning can be looked at en courant, as a path being negotiated through the energy landscape in an attempt, surveyor-fashion, to find the lowest valley.

As computer science per se, a host of interesting problems emerge. Why and in what ways is a variable in a computer program (which is like our old friends x and y from high-school algebra) different from a variable in a PDP system? It is easy, using such an algebraic variable system, to support (an NLP system which caters for the type of recursion epitomized by this bracketed sentence within a sentence). However, this "recursive" capacity, along with several other characteristics of algebraic variables, does not come altogether naturally to PDP systems. We end this chapter by introducing further computational considerations related both to brain and PDP systems, which ease our passage into chapter 5.

4.4.1 Connectionism as experimental neuroscience

The notion of a formal neuron is generally attributed to McCulloch (1989) and Pitts. This notion is simple in the extreme. Section 4.2.3 hypothesized neuron A connected to neuron B. Let us imagine that the threshold of neuron B, a measure of its polarization, is 10 units. Then the impetus required for it to fire must equal or exceed 10. We calculate it by multiplying the threshold of A by its strength of connection to B. In real PDP systems, we are going to have N neurons with threshold *Ti* and connection strength *Ci* connected to B. The impetus arriving is a summation over all of them (Σ *Ti Ci*).

So much for formal neurons: what we are focusing on here is PDP's case for psychological-neurological validity. It rests on the following planks:

1. The CAAM paradigm is psychologically more plausible than lookup memory.
2. Lesionability is possible for PDP systems with some of the same results as for biological neural systems. Indeed, we even find evidence that specific speech disorders such as dysphasia can be induced by lesions on PDP systems.
3. Learning is adaptive rather than all-or-none.
4. Knowledge representation (KR), particularly in distributed connectionist systems where a single concept may be distributed over several nodes, yields high interaction between different items. We have time and again noted how activation of a single word brings up all its contextual occurrences as well before the correct one is chosen. This can easily be modelled with PDP systems. Both human and PDP memory perform well in complex material with an inherently strong semantic organization.

Let's take five. Myles in the diagram 4.4 is using localist representation. Each mode represents a particular concept. Standard KR is of this nature. However, in distributed KR, as in diagram 4.5, the neuron may be doing something very strange indeed! Here, we end up with the scenario where a single item may be represented over several neurons, and conversely a single neuron may be representing several items.

There are however a few serpents in this particular garden of psycho-neurological validity. We have already discussed how conventional algebraic symbols contrast with PDP "symbols": the former seem to be to some extent used by the brain. For example, Music and Language exhibit recursion at least to some extent. The learning involved in PDP often resembles a long slow swim through a marsh rather than the straightforward additions to production-type systems (see chapter 2) of which we are all capable: pattern-recognition comes easily and in a psychologically plausible fashion to PDP, concept-formation does not.

We discuss computational specifics in 4.4.3. One such specific, that of competitive learning, is relevant right here. Normal PDP systems involve a teacher's correcting incorrect guesses made by the system and the adjusting of "weights" of connections in accordance with specific algorithms in order to converge to an optimal solution. An alternative framework pre-sets neural groups to compete with each other for the "right" to recognize a particular pattern or evoke some such chain of events. A related notion is that of Attractor Neural Networks, where the mathematical vectors

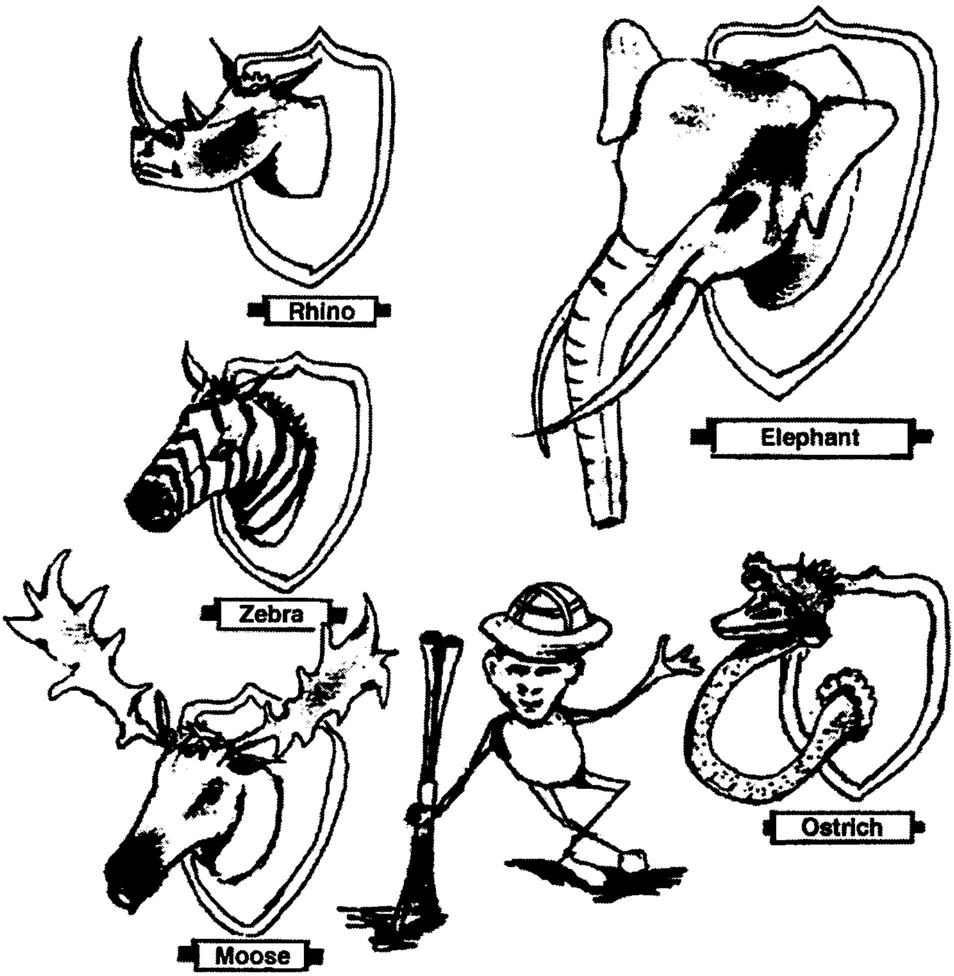


Figure 4.4

representing input patterns are conceived of as being differentially attracted by different locations in the energy landscape. Here we have notions which lend credibility to the construct of competition between neural groups, winner-take-all networks. The fact of massive neural death in early infancy, already noted above, suggests a somber fate for the losers.

4.4.1.1 Symbols among the neurons

"I wish I had said that," said Oscar Wilde on hearing a particularly witty epigram. "Don't worry Oscar, you will" was the reply. The title of this subsection is due to Touretzky et al (1985), who described therein a production system with a PDP

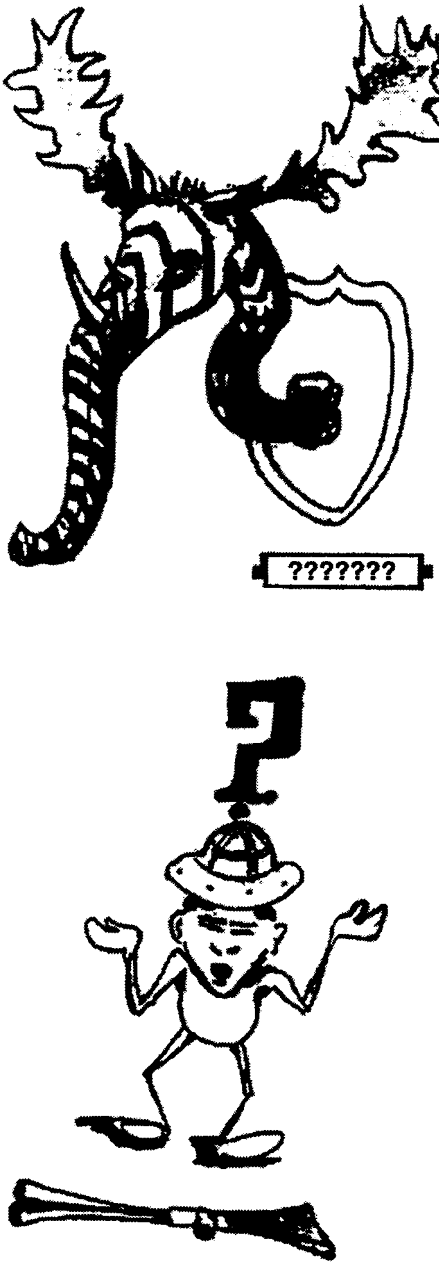


Figure 4.5

architecture. However, its slow learning curve gave rise to the "Touretzky tarpit" phrase, another *mot* of which I am envious! A related famous statistic is a matter of 2,232 samples before such a system learned exclusive disjunction which we discuss below (XOR: see figure 4.6. The single line cannot correctly separate the "True" from "False" cases with input expressed as 1s and 0s). Thus, symbols don't seem to thrive among the neurons: is there an alternative way of conceiving the relationship between explicit symbol and neural activation? Might we not be better off postulating a gradual ascent from the latter to the former, with several well-defined watering holes en route?

To ease our entry into the consideration of this section, let's focus on the neurophysiological phenomenon of "pacemaker" neurons. All neurons fire randomly on occasion, as if warming-up. The firing of pacemaker neurons, however, has been found to conform to certain specific preferred temporal patterns. Recently, it has been postulated that these patterns could be used as "tags" to indicate the significance of other patterns of neural firing. In other words, the message occurs in a medium or context supplied by analysis of the firing of pacemaker neurons. This is quite a breakthrough: we now have neural communication occurring at two different logical levels. Moreover, the notion that neural computation takes place only through the operation of spatial coordinate transformation in an interlaminar state-space must be abandoned. The addition of temporal sequences admits the possibility of several different types of neural code.

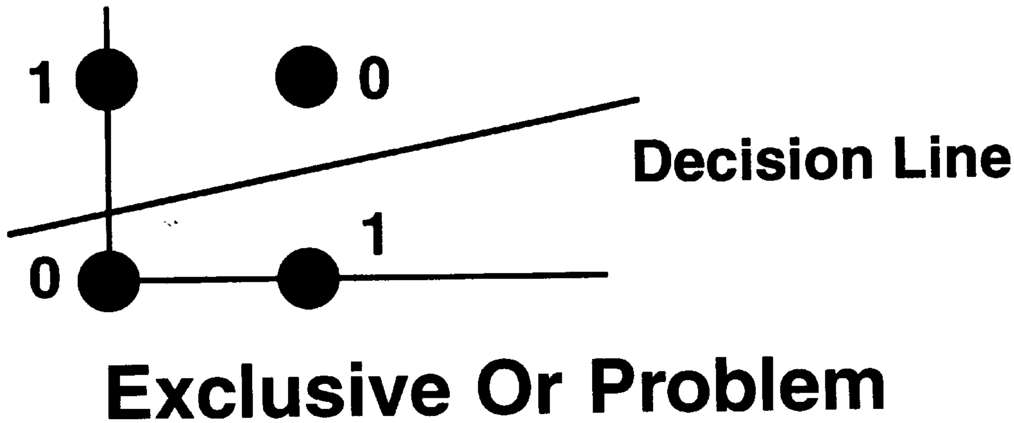


Figure 4.6

It is apposite right now to reconsider another of the perennial canards of Cognitive Science i.e. whether cognition is best conceived of as neurally implemented in only one (propositional) code or in two (logical and spatial). The advocates of the former point of view (e.g. Pylyshyn, 1984) normally rested their case by claiming for digital, computer-like neural transmission. This now seems far from the truth: so too does any opposing view claiming only for a "spatial" language of thought combined with the propositional one. It does rather seem as though the brain is capable of supporting a variety of codes, now pure coordinate transformation, now including temporal sequences also, now perhaps making reference to grandmother cells and symbols structured according to formal rules of interrelation. Kosslyn (1994) adduces brain-imaging data which conclusively demonstrate the existence of a spatial (or imagistic) code.

Dyer (1989) describes PDP systems at various levels from the neural to the fully symbolic, proposing interlevel mapping algorithms. The details of his excellent work need not concern us here. Of much more relevance is his concession of PDP's urgent need for full symbols (p. 81). He argues, moreover, that neural process often builds upon unfinalized, distributed probabilistic guesses at symbols before they resolve their boundaries. Children's early visual behaviour shows evidence of "distributed KR" guesses at colors or shapes which gradually solidify into explicit symbols which can later be built upon. The conclusion is inescapable that neural activity admits of a multitude of forms, with symbolic activity having pride of place in terms of its effectiveness.

4.4.2 Parallel distributed processing as tacit knowing

This section is, inter alia, an overture for the overall cognitive architecture to be outlined in chapter 9. Part of its motivation is a wish to resolve some of the tensions just mentioned e.g. symbol or not. The work of the philosopher and scientist Michael Polanyi is discussed. It is argued that Polanyi's schematization of conscious experience

provides a basis on which the perennial dichotomy of symbolic vs subsymbolic can informatively be discussed and such antinomies as those that arise from the frame problem be looked at afresh.

Polanyi seldom makes reference to computing, and it is at this point that the main theme of this section emerges. Polanyi's distinction between "explicit" and "tacit" is seen as analogous to that between high-level explicit symbols and low-level distributed symbolic patterns. The notion that focal consciousness, or explicit awareness, may be best regarded as a "virtual machine" is introduced and seen to be consistent with some relevant data. However, we shall see in chapter 8 that it doesn't go quite far enough.

4.4.2.1 The necessity for both the symbolic and subsymbolic dimensions

Cowan et al (1988), at the end of an excellent survey of connectionism and its history, open a methodological front on the Classical (PSSH) position. They characterize the classical AI methodology in these terms: first specify the context, next describe the logic of the desired behaviour, and then try to achieve it by using various heuristics" (p. 113). They argue that this approach results in that context-dependence which is the bane of AI (ibid). Connectionism, they argue, can sidestep this stumbling-block. We should note the analogy with Gibson's work on perception: in subsymbolic PDP work, as in ecological optics, the subject/environment relationship is intimate.

However, for Cowan et al, the future success of neural nets hinges on an ability to simulate a "primitive attention mechanism" (p. 115) in the manner of Handelman et al (1989), to take one example. They conjecture that the top-down and bottom-up approaches will eventually merge under the umbrella of "experimental epistemology" (or at least be a part thereof) (p. 116) and insist that progress in the area awaits further knowledge of how ideas and intentions can be realized neurophysiologically (ibid).

Some of Smolensky's (see below) (1990) more recent work downplays PDPs neuromorphic claims and allows it to be judged on its experimental success as a research paradigm. In a reply article, Wilks (1990) emphasizes that the jury is still out on that score. Let us now review the evidence for the prosecution.

Papert (1988) argues that the "cost of holism" can be great for some tasks. Touretzky and Hinton (1985) have shown how a high-level classical description can be translated down to a parallel network: however, the computational cost is astronomical.

It is at precisely this point that Polanyi's approach can prove most useful. The computational cost of thoroughgoing connectionism is too high yet the lack of psychological veracity in classical AI is too glaring an omission. Polanyi's schema allows us to look at classical, symbolic description as valid, precisely because it is supported by subsidiary processes. Either component in isolation is incomplete. Thus, the problem Papert notes of the computational cost of connectionism no longer seems as intractable.

Let us now look in more detail in Polanyi's work.

4.4.2.2 The work of Michael Polanyi

The following account will be taken from Polanyi's two major works. *Personal Knowledge* (1958) inveighs against objectivist "scientistic" notions of knowledge,

insisting that the research process cannot be divorced from the personal commitments of the researcher. Both here, and in *Knowing and Being* (1969), Polanyi is concerned with giving a coherent psychological analysis of the growth of knowledge, and in the process proposes a very specific outline of the structure of waking consciousness. Polanyi's interrelated conceptions of knowledge and consciousness provide a hospitable venue for the Symbolic/Subsymbolic debate.

The distinctions that Polanyi makes between focal and subsidiary awareness are paralleled by a dichotomization between explicit and tacit knowing. He is concerned with awareness as essentially cognitive, so awareness and knowledge are treated as one.

Let us focus on the nature of focal and subsidiary awareness by referring to specific examples. Subsidiary awareness is of the impress made by the hammer on the palm of the hand; focal awareness is of driving in the nail. Subsidiary awareness is of the particulars which constitute an object; focal awareness is of the object. Nor is subsidiary awareness to be identified with the "fringe of consciousness": as one writes, Polanyi argues, one's subsidiary awareness of the pen is by no means compromised or incomplete, though one is (hopefully) focally aware of the content of what one writes.

Every act of consciousness has these subsidiary and focal components and tacit knowing is based on the former. Indeed, this dual structure of awareness, Polanyi insists, is why humans do not fall prey to the frame problem: the fluctuating, changing objects are monitored subsidiarily to yield solid percepts at the focal level. We may add to this the special-purpose hardware which implements processes such as the oculomotor reflex.

Yet, at moments of creation, it is tacit knowing which predominates. Moreover, tacit knowing is capable of self-correction. Ultimately, Polanyi argues, all knowing is tacit in nature, or based on tacit knowledge.

Let us draw the analogy out explicitly. Tacit knowing as structure and subsidiary awareness as process can be usefully modeled by PDP systems with a capacity for some auto-regulation. Yet, as we have seen Cowan et al argue, there must exist also a focal, perhaps top-down component. At this point, let us examine the cognitive architecture which forms the central postulate of this section.

4.4.2.3 A proposal for a mixed cognitive architecture

Polanyi's schematization distinguishes between a single focal and myriad subsidiary elements of awareness. It provides also a framework for the problem of embodiment in emphasizing the subsidiary nature of body-awareness in the manner we have seen so much of in Merleau-Ponty (1962). Let us now look at Polanyi's work in a computational context.

The analogy between top-down and focal has been dwelt upon. Subsidiary awareness we can regard as treated by PDP systems. Where does all this get us once the neatness of the metaphor loses its novelty? What follows is some speculation as to what the consequences of Polanyi's formulation would be for current AI.

The first point is that subsidiary awareness can cast new light on the frame problem (Pylyshyn, 1987). The fluctuations of objects are handled by auto-regulating subsidiary

systems. The next point is that subsidiary systems can address the problem of context change. We can regard the myriad subsidiary systems as monitoring a stimulus environment until a salient change occurs Moreover, the word "myriad" is used advisedly: as Johnson-Laird (1983) has indicated, following Marslen-Wilson's findings, the presentation of a single word activates it in all its possible contexts for a short time, though only one of these contexts finally is chosen. We witnessed analogous findings in Sperling's experimentation in chapter 2.

Therefore, we can regard subsidiary systems as active content-addressable neural nets which spring to life and enter focal consciousness once sufficiently determined by the environment i.e. once the content reaches that certain threshold at which the auto-associator "fires." In the meantime, until they so enter, they actively monitor stimuli and can act to preserve the integrity of a scene despite change in the manner described in 4.4.2.2. Moreover, such connectionist systems have at least a degree of neurophysiological plausibility. Smolensky's (1988) notion of a virtual rule interpreter parasitic on tthe truly causal subsymbolic processes is analogous to Polanyi's schema (see below).

What of focal consciousness which doesn't seem to have any hardware support? Bateson (1979) has characterized this type of consciousness as a short-cut to implement specific goals and notes its lack of place in a natural scheme of things. In fact, the best analogy for focal consciousness in computer science may be an adaptation of the notion of a "virtual machine." We comment at length on Bateson in chapter 5. Let's plunge into computing. We'll be there for a while.

One specific example springs to mind of virtual machine use, and its all the more fortuitous that it is at least vaguely AI. The designers of the best seller Q+A (an integrated software product comprising a database and NL interface) were confronted with a difficult question: how to build an NLP system with decent linguistic coverage that could work on the slow CPU and limited memory of an IBM PC? The answer was to compile the syntax rules and semantic functions into custom P-codes. Hendrix et al (1987) explain:

> "A p-code is a machine-language instruction, but for a virtual machine rather than the physical hardware. The p-codes are executed by an interpreter and emulates [sic] hardware of a different design" (p. 254).

The result was enormous savings of both space and time. Obviously the notion of "virtual machine" is an extremely common one in Computer Science (Lister et al, 1988) but here the analogy is particularly apt.

Therefore, we bring the analogy a stage further: focal consciousness comprises top-down processes which, though supported by and dependent on subsidiary processes, operate by completely different rules on the same hardware. Moreover, the same process can be implemented by PDP or top-down systems as Touretzky et al (op cit) have shown: the latter is much faster.

There is no question but that this involves a new type of cortical computation from that which PDP systems attempt to simulate. However, Gregory Bateson (1979)

vehemently argued over the course of more than a quarter-century that focal consciousness was precisely that. In conclusion, it does indeed seem that Polanyi's distinction between the focal and subsidiary, between the explicit and tacit, may provide a vocabulary with which one can usefully discuss an enormous range of phenomena, psychological and computational alike. In particular, to re-iterate a point made earlier, use of this vocabulary may shed much light on the Symbolic/Subsymbolic debate, while not perhaps fully explaining aspects of focal consciousness.

4.4.3 PDP as Computer Science

4.4.3.1 History of PDP as a Computing Paradigm

A historical approach is by no means inappropriate here. The groundbreaking work of McCulloch and Pitts, mentioned above, led inevitably to a huge upsurge of interest in the area. The fact that the model of the neuron which was being used was a near-grotesque simplification failed to turn away the faithful. Their central argument was that any neuron could be described in binary form using the resources of the then-burgeoning science of information theory. Such description could lend itself to computational implementation.

During the 1950s much research was done, on pattern-recognition using the "perceptrons" inspired by the earlier breakthrough. The central notion was simple: a photosensitive surface was directly connected to an output layer of neurons which could, for example, if hooked up to a speech synthesis unit output the word "seven" if a shape with 7 items were presented, "four" if a different shape was presented, etc. Research on PDP has always been highly mathematical in its analysis: a formal proof was established that these perceptrons could learn to recognize anything which they could potentially recognize (The Perceptron Convergence theorem). As always happens in AI, a serpent entered. Frank Rosenblatt, one of the major practitioners, was the first to notice it.

Perceptrons work by classifying patterns. As we note below, that is only one of a number of principles which can inform PDP computational processes. If looked at visually, the only kind of classification which Perceptrons are capable of is that of drawing a line between accepted and not-accepted such patterns, as viewed mathematically. This allows them to distinguish X and O, but not C and T. (The former pair are linearly separable, the latter are not). Likewise the group of patterns which comprise successful exclusive disjunction (1 and 0, 0 and 1, 0 and 0 – see diagram – in the formulation in chapter 2, p and q, p and q, p and q) were similarly outside its scope. A classic book by Minsky and Papert (its arguments were recently resurrected in Papert, 1988) collected a number of such proofs. PDP was seriously ailing.

Like all history written by the (erstwhile in this case) victors, the Papertian account fails to emphasize the solution tentatively proposed by Rosenblatt to this problem of "linear separability." Briefly, as expanded in McClelland et al (1986), it involves adding (a) hidden layer(s) between input and output. Now patterns which are separable only by planes (sometimes hyperplanes in n-dimensional hyperspace) could be classified. However, the convergence theorem cannot be proven for this case. Following the work

of Rumelhart, Touretzky, Hinton and physicists such as Hopfield (ibid), PDP acquired the sheen it still possesses as (at worst) a fascinating mathematico-physical formalism. PDP systems have, with varying degrees of success and credibility, decreasing as we go across this list, learned to recognize patterns such as faces, pronounce English, assign roles to actors in sample sentences, featuring prepositional phrase attachment, and form the correct past tense for a large range of English verbs.

PDP implementations can be software simulations, where each neuron might be represented by a function in a high-level programming language accepting as values for its parameters the inputs from neurons below it in the net, or alternatively actual hardware design, where every neuron corresponds to a separate processor. What all the various implementations share in common (Arbib, 1987) is at least one of the following features:

1. Use of networks of active computing units, each restricted to a simple functional structure.
2. Parallelism: the neural reality thereof certainly gives pause
3. Encoding of semantic units over groups of neurons.

4.4.3.2 Functional classification of PDP systems

We review an architectural classification later. An appropriate functional classification would distinguish the following types:

1. Pattern classifiers. These would categorize Patterns 1… N (be it a set of faces or speech sounds) correctly by correctly by outputting responses 1… M as required. The best example is Nettalk (Sejnowski et al 1987) which learned to pronounce English text. Most conventional "Neural Networks" perform tasks such as this, occasionally on content as abstract as stock market trends. The success of these systems often involves extremely complex interactions between thousands of neurons in the net. They can perform in complex, unpredictable ways and include as a special case.
2. Auto-associators. Here, the task is that of recognizing the very pattern which the network encodes e.g. "Shall I compare thee…?" should evoke the rest of Sonnet 18 in an auto-association.
3. Pattern Transformers. These would be expected to transform one pattern, such as an English infinitive, into another, an English past tense.
4. Inferencers. These could supply rules of semantic relationship to handle issues such as ambiguity, the bane of NLP. So far, with extreme difficulty.

4.4.3.3 PDP and Archimedes

Aleksander and his colleagues (see Aleksander and Burnet, 1984) developed several visual systems with a connectionist-inspired architecture. We are concerned only with the realization of Archimedean subject/object differentiation attempted in these systems, so the technical discussion will be brief. Their major initial insight was that recognition of shapes such as faces on an all-or-none basis was an extremely fragile technology which could greatly be improved by partitioning the faces into, say, 32,768 distinct parts. The task would be perhaps that of recognizing which of 16 different

stored images corresponded most precisely to an incoming stimulus. Their first solution was that of allowing each stored face to "vote" on how many of its 32,768 neurons corresponded to the incoming stimulus. The face which got the most votes from its constituents was seen as the winner.

Now let's imagine that two of the faces are those of identical twins, one with a mole on the upper left cheekbone. The mole might be sufficient to distinguish them in most cases, but let's now allow for the wearing or not of glasses, moustaches and indeed toupees. Aleksander and his colleagues found that this kind of problem in a milder form could be solved by adjusting the initial training period. Instead of simply training discriminators to respond to static shapes, the discriminators would be taught to respond over a succession of trials to a pattern comprising both the static shape and its own response to that shape. The added information afforded by its own action greatly enhanced the formal power of each discriminator.

And so back to Archimedes. He notices some definite effects due to his body's volume and invents hydrostatics in the process. Unquestionably, ability to notice his effects on the world in subsidiary awareness increases his computational power. Suddenly that subsidiary awareness becomes focal as he remembers his promise to King Hiero of Syracuse. It will be argued in chapter 8 that this monitoring of one's effects is more than a simple feedback mechanism or indeed a servo-mechanism. In fact, it will be maintained that it is part of a larger process of attempting to realize oneself through the world, an attempt which holds as true for symbolic domains as for physical.

4.4.3.4 Computational Paradigms in PDP

A. *The Perceptron.* We have already looked at this in some length. As a learning automaton, it is limited in the extreme. The learning algorithm is elementary. If the system initially fails, the weights of connections are adjusted to an extent directly proportional to their effect. Even here, we need to learn something about how linear algebra is used in this area. Features in the domain in question are represented as vectors which may have values along M possible dimensions. The weights are also represented as vectors and the product of input by weight vectors in a single-layer system gives the output. Better still, if the length of the weight vector is unity, the output is simply the projection of the input on the weight vector. The "delta rule" in this case states simply that the change in weight from neuron i to j for learning must be a constant (the learning rate) multiplied by the perceived error of the output neuron j and a representation of the activity of the input neuron i.

B. *Backward error-propagation (BEP) (see diagram 4.9).* This remains by far the most popular PDP algorithm. Essentially, it describes the computational process required to adjust the weights of the connections in cases where there are one or more hidden layers between input and output. As noted above:

1. The relationship between input and output is not linear. This means, given an input of magnitude x, we can't assume the output will be some linear function of x.

2. Patterns represented by input vectors which require N-dimensional space for correct separation can be handled with BEP.
3. There is no guarantee that the solution found will be optimal.
4. A great deal of the engineering involved in getting a BEP system to perform a specific task used to be"ad hoc": someone would decide on the fly, just how many hidden layers and how many neurons in each, though this has been addressed by various authors, such as Fahlman.

Learning is implemented by changing the weights at each level in such a fashion as to minimize error. Moreover, we may a priori decide the rate at which the system should learn: ideally, slowly for tasks which require fie discriminations (e.g. pronunciation), quickly for other tasks e.g. distinguishing X from O. (A full mathematical treatment of BEP can be found in McClelland et al, 1986, pp. 322–326.)

(The BEP algorithm can also be found in a simplified form in Johnson-Laird (1988, p. 187) where it is arithmetically expressed.)

For the n-layer BEP situation, we have to consider the transformation of the input vector iterated several times. Again using our vector notation, we consider the weights as plotted in an x-dimensional "weight space." We need to establish that the delta rule can, at least with some simplifying assumptions, perform a gradient descent on the error in the situation BEP requires. Essentially, we have to establish that the error measure of E in equation 2 below, differentiated with respect to weight, is proportional to the change in weight prescribed by the delta rule. Let's look at how the two major entities are calculated:

1. Output values from each neuron are computed by the application of a sigmoidal function. Let xj be the input to neuron j.

$$\text{Yi, is output} = \frac{1}{1 + e^{-xj}}$$

2. The total error of the network is calculated at each trial:

$$E = \frac{1}{2} \sum_i \sum_j (y_{j,i} - d_{j,i})^2$$

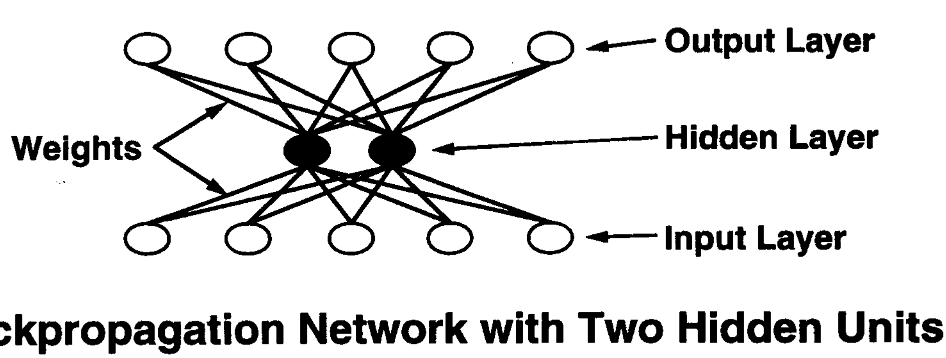


Figure 4.7

where j is an output unit subscript, i is a pattern subscript, d is the desired and y the desired values of the output unit's activity.

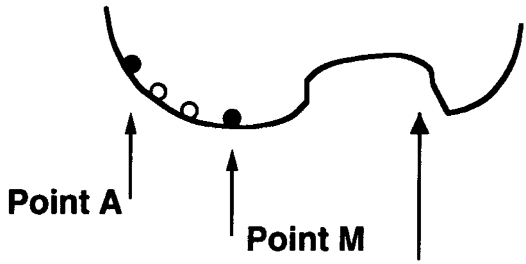
BEP is neurologically implausible. Moreover, psychologically speaking, we don't learn only in cases of error. Hinton has recently been experimenting with self-supervised BEP, which would counter both objections.

C. *Hopfield Nets and Boltzmann Machines*. John Hopfield's current work involves issues as disparate as simulating slugs in neural networks and radical claims about the nature of consciousness (in a claim with which we take issue in chapter 8, he contends consciousness is potentially available to computers). His earlier work proposed one brilliant physical analogy for both the structure and process of groups of neurons. Let's dwell on thisstructure/process point for a moment. Neurons can be seen, in concerted action, as cohering to certain distinct structures. Conversely, individually active neurons might group together into structures whose stability depends precisely on activity of the neurons therein. From 10,000 feet, moving ocean waves look like static features of a seascape.

Ferromagnetic cores are another case in point, and they are the physical analogy which Hopfield initially suggested for brain structure and process. They comprise lattices of individual atoms each of which has a particular magnetic orientation. Yet the ensemble is stable, despite the activity of each of the individual members. Indeed, there are a succession of such stable states of the lattice, leading to one of minimum energy. In diagram 4.6, the current state of the lattice (or neural network) can be represented as a point in the (wavy line) energy landscape. Starting at point A, the ball must move until it gets to point M, a stable state. However, we're back at a BEP-like problem: we don't know if this is the optimum state. For that, we need the addition suggested by Boltzmann machines which we discuss presently.

KR is done in Hopfield nets by the energy landscape described above. The local minima facilitate CAAM. Let us continue the physical metaphor. The cooling of ferromagnetic cores was, unsurprisingly, discussed at length in the Los Alamos H-bomb project. Essentially, what they needed to be able to do was give the wavy line a tug, like to a rope attached at one end to a wall and allow the ball bearing settle into an absolute minimum. Learning is thus implemented as finding an absolute minimum of an energy landscape. One application has been solution of the traveling salesman problem i.e. the NP-complete problem (see chapter 5) of plotting the optimal route through a set of cities for a salesman. The trick in simulated annealing, the Las Alamos technique is to flip the "spin" of one of the atoms and view the result. If it's more stable, stick with it: otherwise, revert to the initial state.

D. *Adaptive Resonance Theory (ART)*. Like BEP, ART is used mainly for curve fitting. However, unlike BEP it acknowledges that explicit teachers don't occur in nature. Both BEP and Hopfield/Boltzmann architectures require teaching to a degree unrequired in ART. The categories to which incoming features are judged to be similar compete with each other: ART is unsupervised learning (see diagram 4.7.) Many notions from



Energy Landscape with Trajectory of State Space

Figure 4.8

biology are used in ART, making the claims for neurological plausibility (neuromorphism) all the stronger. Indeed, the component neurons seek to emulate the membrane properties of neurons by obeying non-linear differential equation descriptions. A locality principle prohibits interaction except between adjoining neurons. ART works well as in distinguishing items of different categories. ART systems are more biologically plausible than SOMs (see just below) and involve the possibility of the network itself determining the granularity of its analysis of the world.

E. *Self-organizing maps (SOMs)*. Again, the structural principles here are drawn from biology. In particular, the SOM uses an analogy from processes at work in the mammalian cortex which convert sensory signals into features. In SOMs, each neuron is connected to its section of the environment via a set of fibers which may be excitatory or inhibitory. The neurons are typically arranged in a two-dimensional lattice (like those in BEP, but without the input/output pointers). We discussed topographic mapping above in section 4.3.3. We can achieve it in SOMs provided that excitation across the neurons varies in a regular and continuous fashion with the sensory input signal. What essentially we're trying to achieve in SOMs is that the probability distribution of the input set will be reflected in that of the output set. For map formation, training should take place over an extended region of the network centred on the maximally active node.

F. *Sigma–PI learning (SPL)*. Again, this technique is used for learning continuous maps and the technique gives PDP expression to Gibson's notion of organism/environment interaction. We noted above Cowan et al's appeal for alternative AI methodologies to those which pre-map the domain and then act on it: with this type of architecture, this appeal has been heard and responded to. Essentially, SPs work by function approximation for any type of reasonably continuous function. The teacher input is the correct values (f (x… z) for input values x… z. (see diagram 4.10). They are particularly useful for situations where complex combinations of neural firing occur.

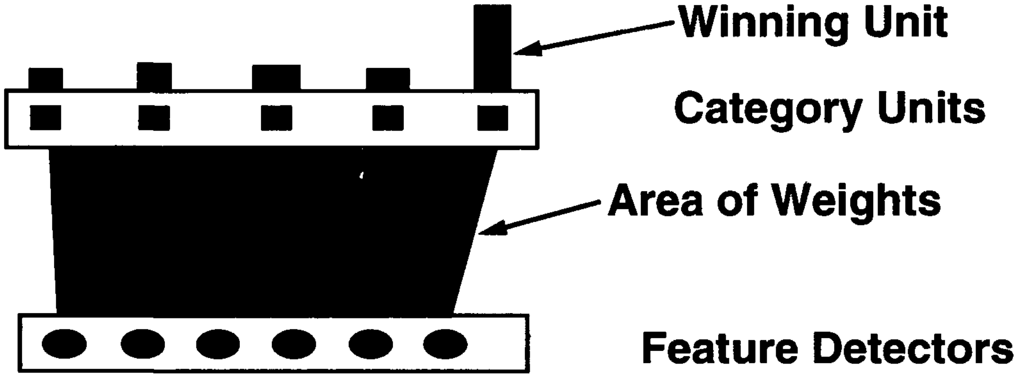


Figure 4.9

G.. *Conclusions*. We have examined the major computational PDP architectures. With ART and Sigma-PI, we entered the domain in which Gibsonian subject/environment relations attained computational expression. In this, even more than in its exciting helter-skelter of physicobiological models, PDP shows signs of becoming an importantly innovative approach to major issues in Cognitive Science.

4.4.3.5 PDP and symbols

The final two PDP architectures we looked at are PDP at its most radical, potentially informative and most removed from the world of conventional symbols. It is indeed possible that they are good neurobiological models for primitive perceptual processes: however, we're going to need some other principles of operation in order to support full symbolic cognition. PDP systems fall down on a number of points here. In the first place, form is not wholly separate from content in these systems.

The major issues in the inadequacy of PDP for full Cognition relate to the nature of symbols. These at least are problems for PDP (there may be more) versus GOFAI (Good Old-Fashioned AI).

1. Symbols are variables in GOFAI with its conventional algebraic treatments of them, but it is difficult to achieve this in PDP.
2. Recursion: we noted this above. In conjunction, we can note that recursion leads to (potentially) infinite generative capacity.
3. Memory management. The notion of a variable occupying a discrete address with changing tenancy does not come easily to PDP except (obviously) at the computer architecture level.

It rather looks as though these aspects of symbols are unavailable even to higher animals as well. These and other aspects of symbolic behaviour are often lumped together under the general umbrella term "sytematicity." It is perhaps disingenuous to continue using this contra PDP. Let's, for example, cast our minds back to section d of the discussion of Piaget in chapter 2. There we saw that humans have difficulty with

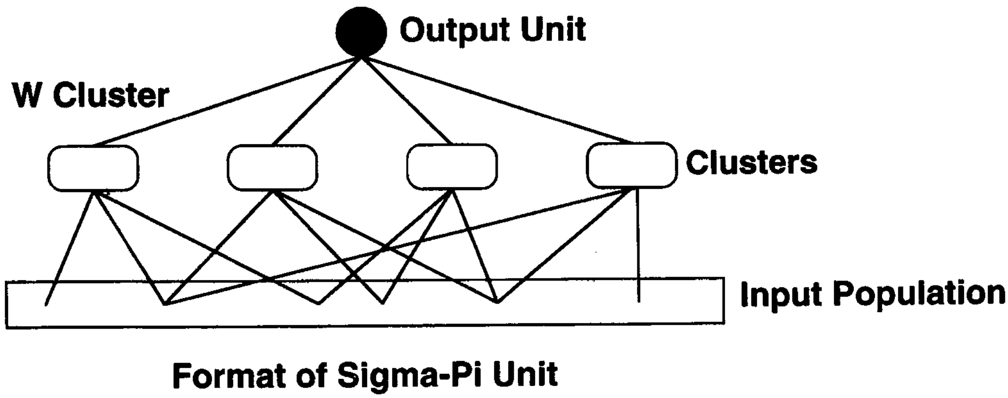


Figure 4.10

form of Modus Tollens: unless the content is adjusted to something to which they are accustomed, they tend to get the inference wrong. Is this altogether different from PDP systems which can function only in one specific domain?

Paul Smolensky (1986, 1990) has made a sustained attack on the symbolic/subsymbolic issue while engaged in his main pursuit of attempting to formulate mathematically rigorous foundations for CS. He does not doubt that the mind is, in a real sense, a computer; he sees the major issue as that of fully describing symbolic behaviour in the necessarily subsymbolic language of neural function. Language is the ultimate test of the validity of this account; most attacks on PDP have focused on its inability to deliver systems which can plausibly emulate human performance on such tasks as derivation of past tense forms of verbs. More generally, the requirement of "systematicity" in its original form insists that PDP systems should manifest the same grasp on distributional regularity as humans; to say, for example, that X loves Y, where X and Y are human, immediately allows one to construct the syntactically correct (if not pragmatically inevitable) "Y loves X."

Smolensky's foundation for CS is the principles of Harmony Theory. The cognitive system is viewed as an assembly of atoms with a capacity to draw inferences consistent with the knowledge in these atoms. Harmony Theory can specify the well-formedness of the activity (i.e. the harmony) of any such system vis à vis others given the same input data. It is thus, in a sense, the PDP correlate of measuring the degree to which a system obeys the principle of rationality. Harmonic grammars allow sentences which satisfy a set of "soft" constraints identifiable as the grammar. Smolensky has demonstrated that each level of the Chomsky hierarchy is emulable by a class of harmonic grammars. If we allow ourselves to rank the constraints, with constraint i stronger than the sum of i +1 to n (i.e. than any below it), we end up with that extension of Harmony Theory known as Optimality Theory which has proven particularly powerful in the case of phonology. Time will tell whether other phenomena of language will surrender as easily to this type of analysis.

Smolensky has been much concerned with the objections of systematicity. He is willing to concede an explanatory role, but no causal one, to the rules of grammar. To understand his reply to these objections in detail requires some immersion in linear algebra; it suffices for our purposes again to note that all the basic units in PDP systems, be they incoming/outgoing patterns of activity or the units in the net itself are described mathematically as vectors. The instantiation exemplified in the X, Y example above can be handled by "tensor product" of vectors. It is important for Smolensky's formalist purposes that such solutions be consistent with the formalism chosen; it must hang together as a single mathematical system. Therein lies the greatest strength and weakness of his approach. The neural reality of entities such as hypercomplex cells indicates that nature sometimes takes short cuts to the same goals Harmony Theory trudges toward. Smolensky will himself admit that much work remains to be done in circumscribing the space in which his systems even begin to learn, given their current slowness. The size of the space involved suggests modified innatism may be a mathematically inevitable for those in the PDP area (as accepted in McClelland et al, 1986). Of more significance for our purposes is the ignoring of experience itself that the "mind = computer" equation requires. The integrity and ingenuity of Smolensky's research initiative will no doubt eventually lead him to confront this issue.

It is the thoroughness of this work which gives one pause. Smolensky has demonstrated how formal languages at each level of the Chomsky hierarchy can be realized without any "deus ex machina" notions such as hypercomplex cells. Any resulting systems will be as yet implausibly slow, but nonetheless successful. One possible synthesis allows that symbolic cognition is initially of the nature Smolensky describes, but that in its equilibration drive the brain can abstract from its own activity and compile the symbolic behaviour down into ever more complex forms, for example complex neurons. This fits well with how we learn language and other symbolic skills.

While on the topic of emergence and GUTs of cognition, it's apposite to note the claims of theorists of "complex systems." Essentially, they posit that as a property of systems that at certain points "at the edge of chaos" order emerges, manifest in ideas, increasing returns in economics, consciousness and so on. The pell-mell of connection activity in the brain make it a complex system par excellence. However, much more needs to be known about the precise conditions which foster order as an immanent property in this fashion.

4.4.3.6 The Brain as a Computing Device

We have already noted several issues here: the slowness of neural impulse, the parallelism, the sheer scale, the astronomical number of connections, the redundancy which gives rise to lesionability, the top-down context effects, the variety of types of KR, the variety of codes. Let us finish by noting the brain's enormously rich connection width, and by noting its contrast with the computer on each of the following characteristics of current computers: their extremely narrow channel responded to by a very fast CPU working together with a large, fast, normally inactive memory.

We've found also that the very structure of the nervous system requires consideration of biological evolution. PDP has been extremely fruitful in suggesting

tentative hypotheses about neural process ranging from its support of high-level cognition to low-level organism/environment coupling.

4.5 The victory of Neuroscience?

4.5.1 The work of Gerald Edelman

Edelman believes in CS perhaps even less than Fodor does (see 1.4.5) though, as we shall see, for quite different reasons. Edelman's (1992) path toward the Holy Grail is the following:

1. A theory of brain and Consciousness (which we review in chapter 8).
2. A theory of perceptual and cognitive categorization.
3. A theory of meaning based on embodiment.

Psychology, he uncontroversially insists, must be grounded in Biology: what *is* controversial is his claim that enough neurobiological data already exist strongly to constrain cognitive psychological theory.

We mentioned Neural Darwinism, significantly called neural Edelmanism by Francis Crick, in 4.2.4. It is apposite now to explain it in more detail. It is a thoroughgoing evolutionary account of how survival of the fittest acts in the brain. Each neuron may have excitatory or inhibitory connections with its neighbors. The unit of selection is the neuronal group, featuring both types of neurons. Edelmanism distinguishes two stages in the path to full cortical form:

1. In the embryonic stage, selection among competing neuronal cells and their processes determines anatomical form and patterns of synaptic connectivity
2. At the postnatal stage, selection among neuronal groups without change in the anatomical pattern shapes the behavioural repertoire.

Interestingly, McCrone (2000) refers to work due to Thompson et al (2000), indicating that a third massive period of growth and decay of neurons occurs during adolescence. This growth happens disproportionately in the frontal and parietal lobes.

Edelman's notions are quite minimalist. Topobiology, which determines organ epigenesis, and reentry complete the set. To explain the latter, we must first realize that neuronal groups differentiate into maps of different parts of the stimulus array. One such map might handle form, another color. Reentry is a process whereby these two maps would form connections with each other on presentation of a stimulus which was evoking reactions in both, in a manner similar to Hebbian learning. Therefore, a given object which, apparently problematically, registers in two maps would evoke the correct response in the correct part of each map, with a strong connection between the two developing. This is Edelman's solution to the "binding" problem. The ethos of this schema is similar to some of the more biologically-based PDP systems above. Edelman extends his system to conceptual thought via a notion of a concept as manifesting the brain's higher-order recognition of its own patterns of response, a notion we saw in chapter 3's treatment of cognitive linguistics.

Many of Edelman's conclusions are very compatible with the framework here: in particular, his qualified realism and selectionism (i.e. survival of the fittest emphasis).

He has harsh things to say about CS and we need to see why. In the first place, he rightly argues that CS must be properly biologically based. However, the brain is not a computer: anatomical maps are not fixed, there is a huge variety of different types of code, and the "wiring" of the brain is near-random. Moreover, brain structure *does* matter.

He characterizes CS in the classic computational terms (or, to be precise as methodological solipsism) we discuss in chapter 5: mental representations with a regular syntax are related to the world by the semantic assignment of symbols to objects in classical categories (Edelman, 1992, p. 230; see also Stillings et al, 1988, p. 335). However, Edelman (p. 234) adduces numerous arguments against this, some of which we've come across repeatedly in this book:

1. The world is not composed of objects in classical categories: the work of Rosch, inter alia, has also demonstrated that our categorization is not classical.
2. Thought and meaning are embodied.
3. Consciousness is required to explain meaning.
4. The merely syntactic operations of computation cannot give a mind/world relationship (but see the end of chapter 3).
5. Language is communicative (i.e. intersubjective).
6. The functionalist notion of programs as mind is incompatible with evolution: for example, the world is not an infinite Turing tape (see 5.2.3).
7. Moreover, cognition gets its content only with respect to evolutionary history.

Much of this fits very well with this book. However, as has already been noted, syntax in a restricted context can give meaning: moreover, Edelman's account of language is simply not adequate. He does give an account of mind with respect to neuroscience.

4.5.2 Recent developments

The 1990s was the decade of the brain, and the data continue to flood in. In this section, we shall attempt to identify some more trends and ideas that will continue to be influential, but have not yet received proper emphasis in this chapter. There is consensus at present on a number of points that we must therefore note. The first such is that some sort of vector coding occurs in the brain to represent various physical quantities. The second is that one activity that the brain must perform is transfer of its tokens across co-ordinate systems of different dimensionalities. For example, suppose we are reaching out to a point in 3-dimensional space with the whole arm. To do so, the brain must calculate appropriate movements by (at least) the collar-bone, shoulder joint, elbow, wrist and fingers. Obviously, it is mapping from n-dimensional space to 3-dimensional space, where n is significantly greater than 3. In our discussion of Paul Churchland, we hinted at this issue; the mathematical solution is the use of tensors, also noted above, or the formally equivalent notion of Lie groups. Hoffman's paper in (Ó Nualláin et al, 1997) champions the use of the latter. In particular, Hoffman argues that Lie groups at a local level parallel neuronal structure; at a global level, they parallel the psychological level of perception. Hoffman offers nothing less than a grand

unified theory of cognition, and I refer the reader to the original article and my introduction thereto.

Philip Kime's paper in the same collection affords an exciting vista for the development of cognitive science. He refers in particular to the work of Pellionisz and Llinas, on which the argument of Churchland above is based. Space and time, we can insist with Kant, are impositions by the brain. Libet (1985 and elsewhere) has shown how the brain operates backward referral in time, if necessary, in order to weave a coherent story. For example, stimulation of a thumb is perceived as occurring before stimulation of the part of the sensory cortex dealing with the thumb. (Similarly, in what will prove very consequential in the discussion of moral responsibility in chapter 8, stimulation of the motor cortex to cause movement of the thumb is easily differentiable by the subject to willed movement thereof – ibid.). The Kantian theme continues; the principles of invariance of transfer across co-ordinate systems correspond, roughly, to Kantian categories. Finally, logical implication (for example, modus ponens), is a matter of geometry; q follows from the twin premises of "If p then q" and "p" for a similar reason to the angles of a triangle in Euclidean space adding to 180 degrees. In all probability, cognitive science will produce findings of this nature within a generation.

The crucial role of temporal coding by the brain – another pillar of current knowledge – goes back as far as Descartes. It is indubitable at this point that spatial relations are often encoded temporally (see Singer, 1995). At a trivial level, scanning a written stimulus from left to right entails that the second is seen later than the first. At a less trivial level, the notion that data items can be bound together by temporal synchrony dates back to Milner (1974). Shastri (1997) emphasises this idea in his computational simulations. He has bought heavily into the notion that LTP is central to memory-formation, and has an elaborate model of the hippocampus. Some quite superb research has demonstrated that sleeping rats' hippocampus replays to the cortex details of a maze learned that day in order to establish it in memory (Schachter, 1996, p. 88). Shastri's work builds into another grand unified theory of cognition through the collaboration with George Lakoff and Feldman, described in our companion volume *Being Human*. Briefly, it is postulated that the x-schema, a neural mechanism equivalent to computational petri nets, is the central construct in cognition at all levels. Our so-called abstract thought is influenced greatly by metaphorical transfer. However, let us note again that even LTP is questioned by reputable scientists such as Gallistel (1997).

Milner and Goodale (1997) have attracted a lot of attention with their positing two distinct streams of information flow in the brain. The received view was that the ventral flow informs as to what an object is, and is potentially accessible to consciousness; the dorsal flow is the "where," unconscious thread. This hard and fast distinction, as might be expected, was questioned by Milner and Goodale, who suggested that the dorsal thread was related to motor process, and the ventral path to perceptual process. One fascinating line of objection is due to Gallese and his colleagues (Gallese et al, 1996). They are willing to grant Milner et al's point about the dorsal thread; however, they find that the tension between the motor and the

perceptual needs to be relaxed a little. They argue that a distinct set of “mirror” neurons are active both in the perception and production of certain actions. For example, a set of neurons in the monkey ventral premotor cortex discharges both when the monkey performs a task and when it sees other monkeys do that task. In humans, Broca’s may be the area implicated, which has obvious consequences for language learning.

Calvin (1996) is likewise concerned about the roots of cognition; he argues that a fast action such as throwing projectiles, which occurs too quickly to be modified by feedback, was the dynamo thereto. (Interestingly, this unavailability of feedback was the argument that Gardner (1985) adduces as the origins of cognitive science at the Hixon symposium.) Burnod (1990) is similarly concerned with identifying a central mechanism at work throughout the brain. He agrees with the consensus on the importance of maps; however, he posits also that billions of cortical columns in the cerebrum handle computational subfunctions. Continuing the metaphor, the individual cells act as memory locations.

As with Milner et al’s ideas, Laberge’s (1997) notion of the triangular circuit will re-emerge in chapter 8. Clusters of neurons in the frontal cortex are seen as the controller of attention. Certain thalamic areas enhance it, by stimulating the appropriate cortical columns. Expression is handled by clusters of neurons in the posterior and anterior cortex that manage perception, action, and plans. Awareness requires participation of a repersentation of self; barring this, it is mere “attending to an object.” The success or otherwise of ideas such as Laberge’s and Milner et al’s hinges on whether they can explain apparent anomalies such as blindsight, where brain-damaged patients (specifically, those with lesions in area V1) show abilities for non-conscious learning. Finally, whether or not it is accepted, as Piaget asserted, that cognition serves affect, the fact that the brain is a gland, bathed in hormones, has come increasingly to the fore (Restak, 1994, p. 205). In a powerful metaphor, Restak (op cit, p. 179) refers to the various brain areas combining together, in jazz-like improvisation, to produce particular effects. And that in a nutshell is why neuroscience is so hard.

4.6 Mind in Neuroscience: summary

Edelman provides us with an opportunity for a short curtain-call: his work syntheses several themes. We have been concerned in this chapter with an introduction to the discipline. This involved first of all categorizing the different sub-disciplines therein before going on to the methodology of neuroscience. After reviewing gross neuroanatomy and being duly impressed with the sheer scale of the brain, we proceeded to discuss neural functioning and how learning might be implemented, about which much is currently being learned. The notion of inter-neuronal competition is a leitmotif here.

We found it possible to maintain the Mylesian position in the face of the neuroscientific evidence: the mild realism is supplied by Edelman and Pribram, and the processes involved in egocentric knowledge seem to have a correlate in, for example, the action of certain neurons in the hippocampus and parietal cortex. One major source of interest was topographic maps in the cortex for most sensory

modalities, with the exception of olfaction. Another interesting point was the extent to which the hardware of the brain seems appropriate for the support of probabilistic reasoning.

We reviewed connectionism under a variety of headings: that of neuroscience, that of computer science, and as a theory of tacit knowing. The accusations of a lack of systematicity were seen as being a little less damning than might apparently seem to be the case. We classified connectionist systems both with respect to their architecture and their use. It was indicated that the more biologically-inspired such models are the most interesting. In their minimalism and selectionist ethos, they resemble the work of Edelman, with whose critique of CS and proposal for a theory of mind in Neuroscience we closed the chapter.

The lessons for our overall theory of cognition are clear. The notion of a body-subject active in exploring the world has now acquired a neuroscientific echo and seems in evolutionary terms valid. Nature, profligate as ever, allows massive death of neurons so that the survivors can better map themselves onto objects both in the world and representing the body-subject's interaction with the world. Another core dynamic principle, re-entry, resolves the binding problem. There is no passive impressing of objects at the level of inter-neuronal dynamics; the realist interpretation is appropriate only at a higher level of description. The paradigms emerging in neuroscience are embedded and equilibriating in precisely the sense we need for the Nolanian framework. The difficulties with full symbolic behaviour can best be explained in the schema here by allowing a general syntactic (a "syntax of thought") system available to all forms of cognition, be it linguistic, musical or kinesthetic (for example, dance often conforms to a grammar).

The notion of a body-subject active in exploring the world has now acquired a neuroscientific echo and seems in evolutionary terms valid.

4.7 Further Reading

Edelman's (1992) *Bright Air, Brilliant Fire* is an provocative and readable introduction to Neuroscience. The collection of articles on Mind and Brain in the September, 1992 edition of *Scientific American* is worthy of attention. The collection in McClelland and Rumelhart (1986) gives much detail on connectionism. Churchland (1990) explores how algorithms may be neurally implemented. Gray (1987) and Margeneau (1984) are useful for those still interested in monism/dualism.

See www.nousresearch.com for the nous brain construction kit.

5. Artificial Intelligence

Introduction

This chapter is intended as an analysis of what AI can tell us about mind. En route, we discuss the main techniques of AI at a general level. Production systems were introduced in chapter 2, parsing in chapter 3.There is no need, for our purposes, to concern ourselves with the implementation of specific algorithms in specific programming languages. Several good texts which do this already exist (see end of chapter). All those texts tend to claim-jump a little. Inevitably, a text which makes reference to the foundations of AI must (if only implicitly) make philosophical assumptions: a text which (as most AI texts do) treats connectionism must refer to neuroscience: a text which focuses on knowledge-based (KB) NLP must concern itself with issues in compositional semantics. Finally, a text on a subject which breathes life into previously theoretical issues in epistemology by incarnating them as computer programs will necessarily claim an urgent importance for that subject which can hardly be denied.

Consequently, it is not surprising that the consensus view of cognitive science is that it is a species of the genus AI. I have argued throughout this book that this is not the case: yet it is important to see where this misperception came from. Essentially, Cognitive Science acquired some of its initial impetus (and funding) from the success of AI programs. This, in turn, led to an over-emphasis on computation in the conceptual armory of CS. One consequence was the notion of CS as the search for algorithms in all its sub-disciplines, and the identification of these algorithms with mind. In Psychology, attempts were made to discuss Cognition mainly as reasoning, and reasoning solely as computation: in linguistics, the process of NLP was seen as a deus ex machina, an autonomous self-contained parser blindly applied to every text: neuroscience as CS has focused on neural algorithms to a damaging extent distinct from their application: we'll see in the next chapter that the categorization processes all of us as humans elicit from our culture has been viewed as a computer program. Not that there is anything amiss with the search for algorithms, per se: the problems arise when this search becomes divorced from questions about the environment which these algorithms are applied and – even more importantly – in interaction with which the algorithms acquired the specifics of their structures. Separation of algorithm from environment is a specifically Cartesian pathology. We discuss this issue in the first section on AI and CS (section 5.1.3).

If this is the first chapter that you, a computer science head who wonders what all the fuss is about, have perused, I can understand your misgivings. Yet another failed philosopher trying to make a tainted buck by criticizing the honest implementational work of AI! The normal career path here has been to scan through the input-output behaviour of AI programs (most such philosophers are programming philistines), dig

up a dead European white male who said something vague about knowledge in a foreign language, let him loose on the (inevitably limited) program, and show that the 99. 9 (recurring) percentage of human behaviour which the program fails to emulate is due to its lack of situatedness, or hermeneutics, or encephalitis. Well, that's not my style. Like you, I've had in the past to make my living as a programmer, and greatly admire the classic AI programs. AI has taught us a huge amount about cognition and epistemology precisely because of the ingenuity of those programmes. It has taught us as much by its failures as its successes, because we know for sure now that, for example, if a researcher as technically good as Terry Winograd says NLP is a very difficult task for a computer, we are unlikely to say otherwise if we attempt the same task.

So let's stick to people who criticize AI from the inside. This will include philosophers who attempted something such as AI before computers (e.g. Wittgenstein in chapter 1) and found it impossible on theoretical grounds, computer scientists/mathematicians who struggled with the concept of computing and found it had certain inherent difficulties, and linguists who confronted the awesome formal system which is language and withdrew overwhelmed. All these various personages left a flag at the point where they stopped their ascent. They also left an account describing how they attacked the particular face of the mountain to which they addressed themselves. That line of attack is the technique they introduced to AI: the final Camp marked by the flag affords a view of just how complicated the task is. Thus, the second section in this chapter, the promenade down the hall of skeptics, will leave us greatly the wiser about the techniques as well as limitations of AI.

We then re-introduce the Computer Science theme of the last chapter. What type of Computer Science is AI? It has had an influence on Computer Science (for example, the invention of time-sharing) through its huge computational overheads: can it have more? What has actually been achieved in AI considered as software engineering, i.e. what software products can be pointed to? We've looked at NLP in chapter 3: is there a general categorization of AI software which holds as true for vision as for automated reasoning as for NLP?

The high-water mark of AI as Cognitive Science was reached sometime between the 1970s and 1980s. At that stage, it was imperative for any cognitive psychologist worth their salary to indicate some kind of computational process, normally filched from AI, for their theory. This trend still to some extent continues today, and we need to discuss it before focusing on the theory of mind as treated in AI. This topic is currently in ferment and we are going to find, to our considerable surprise, that the view of mind emerging from AI is as close to the Greek "Nous" as any metaphor centered on (mind) = (programs running on a brain).

5.1 AI and Cognitive Science

5.1.1 What is AI?

Let's attempt a definition. If we don't define our terms at the start of the argument, we could well be accused of obfuscating basic issues.

> "AI is that aspect of Computer Science which attempts to make computers perform tasks which we would consider indicative of intelligence if performed correctly by humans."

Well, programs which play good chess are still generally considered AI: however, programs which calculate a large payroll quickly and thus conform to the terms of this definition, are not. Indeed, AI is now focusing a great deal on tasks such as walking and understanding simple sentences – which we tend to regard as not particularly indicative of intelligence. We're wrong in so regarding them: under the type of close scrutiny on which AI insists, these tasks turn out to have massive information-processing requirements. Thus, let's try:

> "AI is the study of intelligence as programming."

This may or may not is an improvement, but we'd better define programming pretty loosely. It's going to include conventional software engineering at one extreme and the kind of PDP architectures and agonizing over the nature of symbols we noted in chapter 4 at the other. If at first you don't succeed:

> "AI is an experimental biology of intelligence, concentrating particularly on being-in-the-world as information-processing."

This allows PDP to return to the fold, takes into account such work as Brook's but it's not going to be much use to such practitioners of applied AI as expert systems builders.

A fair general rule about AI systems qua human cognition seems the following: If you find an intellectual task enormously difficult but possible (e.g. expert chess-playing), AI systems can do it brilliantly; if you find a task only occasionally difficult, AI systems can do it badly; if the task is so easy that you don't even consider it a task (conversing), AI systems do it extremely badly or not at all. Insofar as we find a task difficult, we tend to reflect on it and abstract principles to deal with it. We can usually later find an algorithmic description for these principles. Not so with processes such as pronouncing a language correctly, where we've had the help of 4 billion years of evolution. AI investigative methods can often abstract some subset of processes such as articulation or vision (e.g. the syntactic analysis of scenes we noted in chapter 2), and through computational analysis, enlighten us greatly about them: however, the full functioning of a sensory modality or motor faculty in the real world is a quantum leap more difficult and usually far beyond the scope of current AI. Let's stop trying to define it precisely: its modus operandi is going to change as it switches from well-defined areas such as deductive reasoning (if the discussion of GPS below) to the world of computational neurobiology (e.g. the final PDP systems in chapter 4). If you need to ask what AI is, you'll never know.

The emergence of subsymbolic AI has thrown a spanner in the works with respect to distinguishing different levels of analysis of one AI program as well as neatly defining it. Back in the halcyon days of good old-fashioned AI (GOFAI), the following

analysis seemed correct: An AI program can be described as the Knowledge/Logical Level (KL) with respect to its KR formalisms, at the algorithmic level with respect to the specifics of their implementation, and at a final specifically computational level. Unfortunately, this triptych does not work for PDP systems, where the KR often directly informs and is directly informed by the specifics of implementational and computational architecture. One interesting aside is that the KL is now identified with an observer's perception of the functioning of the AI program, rather than any supposedly objective mapping of the domain (see the discussion in chapter 4 of Cowan et al in "PDP as tacit knowing"). We discuss this at length at the end of this chapter and find it compatible with our organism/environment view of mind.

Perhaps AI stands to the rest of Computer Science as philosophy does to its own offshoots. Psychology, originally a daughter of philosophy in its incarnation as experimental epistemology, struck out on its own to lay claim to its own domain: in that it followed its siblings of physics and the other hard sciences. Similarly, lacking another compelling metaphor for intelligent behaviour, Computer Science has frequently found itself forced to turn to human intelligence when looking for models. However, once the technology deriving from this analysis has been established, it is more likely to be discussed on its own terms than those of AI. Consequently, we can't define AI in terms of the content of its investigation.

What of its methods of investigation? We can distinguish here between at least three separate issues (Partridge, 1990):

1. The principles of program development. In that, AI is not terribly different from conventional software engineering.
2. The principles relating to satisfactory input/output behaviour.
3. The scope of the findings emerging from it.

With respect to AI's attempt to abstract the relevant computational principles applicable to a particular domain, we find ourselves with a Wertheimer-like (see chapter 2) two-level classification:

1. "Fine" solutions involving a parsimonious monolithic analysis, e.g. the notion of competence grammar.
2. Solutions which involve the interaction of a (sometimes massive) number of different processes. It should be clear from chapter 3 that NLP, considered as a general task, will admit only of this type of solution.

These types of considerations, taken together, should allow us to firm up on what our notion of AI is.

To finish this soul-searching section, let's briefly mention the kind of issue currently debated in AI. It should be clear at this stage that the GOFAI versus subsymbolic debate (where subsymbolic includes both Mobotics and the later PDP architectures we reviewed) is raging. One of the tasks the discussion at the end of this chapter sets itself is to resolve it, in the sense of providing an overall framework in which it can sensibly be discussed. This framework can perhaps gain in credibility from its links with Merleau-Ponty, whose catch-cries of situatedness and embodiment (in French

"incarnation") are echoed loudly in the subsymbolic world. As we discuss the attribution of the KL level of the designer or observer, we find ourselves referring to "stances." Mind in AI is a much more fascinating and multi-hued issue than even the dreams of its pioneers might have suggested.

5.1.2 The reduced history of AI

Most good stories involve the hero having X, losing it (or not realizing he has it) and getting it back for keeps. Thus goes for the story of Christian salvation as much as any airport bookshop romance. Many writers on the history of AI have been forced into this framework. I invoke the reduced Shakespeare company again to allow these writers their say with a thirty-second history. We'll then step back and cast a colder eye.

A. *The thirty-second Hamlet*

Once upon a time, a group of brave, clever, but misguided young men wanted to build machines which would emulate human intelligence. They had some limited initial success on tasks such as machine translation, pattern recognition and automated reasoning. Being very young, they got extremely excited and told all the military and other funding agencies to give them more money because they were on the verge of creating a real artificial intelligence. However, some wiser, older men such as Pierce (1966); Lighthill (1972) and Minsky & Papert (1969) proved that the young men were, as we said, misguided. The young men, now older and wiser and with considerably reduced research grants, became seriously concerned about issues such as KR and by the early eighties had regained some commercial credibility.

The End

B. *The five minute Hamlet*

The success of early AI did go to its practitioners' heads. We discuss its general principles below. However, just as Rosenblatt anticipated Minsky and Papert, so also neither the Pierce report nor the Lighthill report were the big news they're often portrayed as. For example, the Pierce report, in the manner of the failed philosophers justly denigrated in the last section, took the contemporary MT systems to task on the basic grounds of their incompleteness. One such system, Systran, is still in current commercial use nearly thirty years later (Toma, 1977). The frame problem "discovered" in the Lighthill report had been revealed by MacCarthy years before (Pylyshyn, 1987). So let's leave victor's history and victor's justice aside for a while and try and get inside the minds of the admittedly hubris-stricken but nonetheless brilliant early AI researchers. GPS provides a perfect example of GOFAI.

GPS (Partridge, 1991, pp. 42–43) consisted essentially of the following:

1. A set of procedures which classify the difference between present state (S_1) and goal state S_2).
2. A set of operators to reduce the relevant differences.

3. A procedure for assessing compatability between S_1 and operator.

We have met such a system before in chapter 2. Now, this type of architecture works superbly on tasks such as solving differential calculus problems where the crucial skills lie in correctly categorizing the problem. (Is it trigonometric or algebraic? If the latter, is it a divisor/quotient problem?) then progressively converting it to tractable form. However, even aside from the issues related to situatedness, GPS must be re-created almost in toto to be applicable to another area of application. For the second time, we find that the syntactic level which can cater only for regular combinations of symbols has sacrificed power for generality. Yet, once the domain has been properly mapped, the power of these systems is awesome. By the end of the 1950s, Bertrand Russell had occasion to congratulate the writers of a neater proof in mathematical logic than he had been capable of at his peak.

The central tenet of early AI was the Physical Symbol Systems Hypothesis (PSSH) i.e. that a physical symbol system such as GPS was adequate for supporting all intelligent behaviour. We have seen in chapter 4 how fraught this hypothesis has become, both as a methodological recipe and as a theory of intelligence. However, a science which had in its infancy managed to out-Russell Russell was perhaps due a Promethean fate. The early spectacular successes of PSSH had a contrapuntal line in the PDP of Rosenblatt and Kohonen. Given this explosion of achievement, anything done in the 1960s was inevitably going to be perceived as a relative failure. Therein, I think, lies the problem, of which the Pierce and Lighthill reports were but a symptom, not a cause. Finally, it is true that the 1960s and 1970s witnessed a growth of interest in KR and that credibility returned in the 1980s. We review current trends in AI below.

5.1.3 Foundational issues: Cognitive Science and Computation

Even at its nadir, AI was still exciting. It was still able to provoke intense debate even on relative non-issues such as whether “computers” could “understand” (see chapter 1). To see a computer program translate even a toy sentence, convert even an isolated spoken word into text on screen, or decide what wine you should have with the snake at lunch is impressive in the extreme. By the time CS was beginning to get its funding from institutions such as the Sloan foundation, it was inevitable that it be heavily influenced by AI. At that stage, AI was very Cartesian: its central paradigm was the notion of cognition as computation over a set of representations built up from different sensory modalities. I wish to take this opportunity to discuss the extent to which this idea has (perhaps excessively) influenced CS and why the central issues of CS have to be re-situated in a much larger concept of mind than currently obtains. Let’s look at some of the main texts in the area.

It is fair to say that there exists a great deal of confusion among non-specialists in the area about the precise nature of CS. Different sections of the academic community hold widely varying conceptions of its nature. For psychologists, it consists of that aspect of cognitive psychology which attempts to give a computationally-tractable account of mind. For computer scientists, it is at present vaguely identified with neural networks. In terms of funding, much of its cash comes from its links with AI, which increases the confusion.

For Gardner (1985) the scope of CS is quite clear: "[CS is] a contemporary, empirically-based effort to answer long-standing epistemological problems" (p. 6). Indeed: "Today, CS offers the key to whether they can be answered" (ibid).

Pylyshyn (1984) is even more explicit: "Many feel, as I do, that there may well exist a natural domain corresponding roughly to what has been called 'cognition' which may admit of such a uniform set of principles " (preface, p. xi).

For Pylyshyn, then, cognitive science is on a par with disciplines containing such a set (e.g. "chemistry, biology, economics or geology" (ibid)) in having a precisely-specified subject-area: "The domain of cognitive science may be knowing things… informavores" (ibid). The biochemistry analogy of the introduction is apposite; "knowing things" are to play the role of the gene, and epistemology is a critical theme.

Stillings et al (1987) are even more forthright and Jamesian: "Cognitive Science is the science of mind" (p. 1.). Like both Gardner and Pylyshyn, they stress the interdisciplinary nature of the enterprise of CS, and focus on the disciplines of "psychology, linguistics, computer science, philosophy and neuroscience" (ibid) in their account of the area. Johnson-Laird (1988), whose earlier incarnation was as a cognitive psychologist gives this definition which sets off the first alarm bells: "Cognitive Science, sometimes explicitly and sometimes implicitly, tries to elucidate the workings of the mind by treating them as computations" (p. 9). The disciplines of "psychology…. artificial intelligence, linguistics, anthropology, neurophysiology, philosophy" (ibid, p. 7) are again seen as the most relevant.

Let us pause for a moment to take stock. There seems to exist a consensus on at least these basic issues:

1. Cognitive Science is the science which deals with cognition, especially knowing. Yet – and here comes the knot in the wood – it has aspirations to deal with Mind per se.
2. As such, it must accommodate findings from a variety of disciplines.

To return to the current theme, we noted that instead of focusing on organism/environment interaction over time, a jarring algorithm as *deux ex machina* note was apparent in CS. This note is heading towards crescendo. Gardner (1985) supplies the most complete characterization of the methodology of CS. He predicates five features of CS (p. 38 et seq) from which we can learn much analysis about excessive computationalism:

1. The acceptance of a symbolic level, of a level of representation. This point is amplified considerably by Pylyshyn (1984), varying on the same Cartesian theme:

   > "I will suggest that one of the main things cognizers have in common is they act on the basis of representation" (p. xii).

   It should be pointed out that this is the key-note of AI in CS: if the representationalist ethos is accepted, then the domain becomes computationally tractable. If it can be established that humans work from symbolic representations, then the task of CS becomes that of implementing these representations as programs, and CS seems a priori quite a feasible enterprise.

We've already found cause to attack representationalism on philosophical (chapter 1), perceptual (chapter 2) and methodological (below) grounds: the latter set of objections is going to force us, if we wish to save face as representationalists, to admit that such work as Brook's requires that a variety of types of representation types other then the centralized, symbolic and manipulable ones of GOFAI exists.

2. The use of computers. As Gardner (p. 43) points out, CS could have emerged at any point since the 1940s, but acquired its initial credibility and impetus from the later success of computing.
3. The playing down of the influence on cognition of affect, context, culture and history. This de-emphasis can also be contested on various grounds, which we've discussed at length in chapters 1, 2 and 3. Above all, this playing down excludes the necessary theory of motivation from the theory of cognition. However, as CS reaches for the mantle of "Science of Mind," its adherents research affect (O'Rorke and Otony, 1994), consciousness (Chalmers, in preparation) and social factors (Halley, 1992).
4. The interdisciplinary ethos. Gardner (p. 44) describes CS as being bounded on its extremes by neuroscience and ethnoscience. Its core comprises cognitive psychology, AI and large amounts of both of linguistics and philosophy, which is obviously in keeping with the structure of this book.

To complicate the situation, some AI researchers, flush with the success of their systems in micro-worlds, feel disposed to hold forth on topics as diverse as selfhood, consciousness, the nature of the soul, and freedom of the will (Minsky, 1986, is a fine example) while holding fast to their original, restricted set of computational considerations. Winograd (1990) argues that this is a dangerous trend. Nor is this disease confined to computer scientists. Johnson-Laird (1988) has an equally wide range of interests and an equal lack of appreciation for the complexity of the issues he raises. Indeed, in true Messianic style he offers eternal life through simulation of personality (p. 392). The broadcaster and neurophysiologist Blakemore (1988), in his popular TV series on the mind, within the space of two pages (pp. 270–272) first of all emphasizes the autonomy of moral issues, and then claims that they also fall within the domain of neurophysiology. There is a very serious problem here which we discuss under the heading of selfhood and consciousness in chapter 8.

It is worthwhile again detailing what one version of the current foundation for CS, as understood and taken to task by Edelman actually looks like. The essential assumption is that there is an a priori order in the world which can be read by a mind such as a Turing tape is by a computer. Mind is the set of programs run on the brain, and just as the particular computer is unimportant, according to the functionalist doctrine of "multiple realizability," because the private language can do the mapping (1.3.3), so also is brain structure (see Edelman, 1992, pp. 13–14 and above for counter-arguments). Cognizers operate with syntactic processes on representations. Semantic interpretation maps articulated functional states onto some domain of intended

interpretation. Human thinking, which may be described as cortical ratiocination, involves goal-driven behaviour over semantically interpreted structures.

It is also worthwhile considering another aspect of the current foundations of CS as suggested by Pylyshyn (1984). In 1.4.4.2, we mentioned his notion of "functional architecture" as the touchstone for equivalence. He insists, moreover, that the choice of the structure of transducers is of critical importance for the science of cognition. They must act on physical, not symbolic entities: thus the violence of the attacks on Gibsonians from Fodor and Pylyshyn. Their insistence that there are no constraints on affordance is well-taken: part of the task of this book is to supply a via media.

Gardner regards CS as epitomized by such work as Marr's on vision (5.4.3), or Johnson-Laird's on reasoning. However, it is difficult to see how such issues as the affect (de Sousa, chapter 2) and consciousness can be handled. Let's sound a few sour notes.

We discussed several more of Edelman's reasons for suggesting the whole enterprise is ill-founded in 4.6. Here are yet two others, which should by now be familiar:

1. The exclusion of affect and consciousness, which Pylyshyn admits is likely, diminishes the science.
2. Only one type of objectivity, i.e. that which obtains when a neat semantic characterization of the domain exists, is catered for in this schema.

We discuss the new foundation again in Chapter 9.

Edelman's position on meaning, i.e. the insistence that it requires consciousness and embodiment, is a distant echo of the work of Michael Polanyi (1958) and all the more secure for this resemblance. The accent on consciousness is expanded on by Searle (1992), who finds it scandalous that a science allegedly concerned with Mind should ignore its conscious aspect. Moreover, Searle insisted that neither materialism or dualism is a tenable, or indeed a coherent position. However, Searle (1992, p. 228) is after bigger game; the limitation of inquiry in the sciences of mind to two levels, i.e. the neurophysiological and the phenomenological. This is in explicit contrast to the central tenet of Cognitive Science, as proposed by Dennett (1993, p. 195): "There is a level of analysis, the information-processing level, intermediate between the phenomenological level and the neurophysiological level."

Several good reasons exist for preferring Dennett's account of this particular event to Searle's. The first is that, having abandoned one level of analysis, there does not a priori seem to be any good principled reasons for not abandoning others. For example, the neurophysiological level can successively be reduced to levels in which the explanatory frameworks of chemistry and sub-atomic physics are the most relevant. Secondly, Dennett's central tenet does not strongly constrain Cognitive Science; it can be interpreted as signalling that such a level is interesting and important without requiring one to buy into the notion that it is intentional and cashing out consciousness in this way. Thus interpreted, this tenet sits easily with the viewpoint on the study of mind outlined in this book.

The most recent thorough attempt to found Cognitive Science on classical lines is due to Von Eckardt (1993). Her argument on Cognitive Science is in itself powerful enough to merit attention; however, she explicitly denies that Cognitive Science is in Kuhnian crisis, but rather is an immature Science with an implicit set of commitments (pp. 30–31) which her book succeeds in making explicit (p. 13).

Immature science is exemplified for Von Eckardt (p. 353) by notions such as the fluid theory of electricity. A paradigm change, on the other hand, could be provoked by a phenomenon such as black-body radiation. Let's imagine that Physics had continued to ignore black-body radiation, and had continued in its long-accustomed path; such was the case for the Ptolemaic Universe. Is this self-blinkering not precisely analogous to the past attempts in Cognitive Science to establish a science of Mind without Consciousness, affect and social factors? What we have in these attempts is an almost wilful ignoring of explicanda in the manner of the Geocentrists. The ignoring of these factors has a history corresponding in its complexity and controversy to the cosmological issue, and by coincidence converging in the latter respect on the same individual. It was in fact Galileo's distinction between "primary" and "secondary" qualities which first exiled much of mental life from the scientific framework. It behooves us for the moment to consider Von Eckardt's exemplary account of Cognitive Science.

The central issue is this: if Cognitive Science really is to become the Science of Mind, it must include affect, consciousness and social factors. Yet the Foundations laid by Von Eckardt do not admit these factors any more willingly than do those laid by Pylyshyn; they can perhaps later be confronted (ibid, p. 341). Von Eckardt does not relax this tension, nor is it her intention to do so. On the contrary; she is concerned with making explicit the assumptions with which Cognitive Science researchers have to date implicitly being working. In fact, her book can be read in this light as a rather more thorough demolition job on conventional Cognitive Science than that of which Searle, Edelman and their cohorts would have been capable.

Let us first consider her characterization of Cognitive Science as an immature science, rather than one in crisis. She is unwilling to accept that Cognitive Science is capable of crisis for two reasons; firstly, it is too immature as a science; secondly, Kuhn's notion of a paradigm is poorly formulated. She is willing only to accept his notions of a "disciplinary matrix" and "exemplar." In fact, Cognitive Science is to be viewed as a research framework, perhaps the precursor to a new science.

Let's consider the latter point first. The notion of a "paradigm" at least has the virtue of being generally recognizable; more importantly, we lack any more appropriate word to capture scientific revolutions such as that involved in the transition from Classical to quantum physics than "paradigm change." Here, the term is being used on this "as if" basis; the alternative formulations to Kuhn's like Laudan's (ibid) need a similar concept of paradigm. Secondly, though Cognitive Science may be immature in the sense Von Eckardt describes, the attempt to construct a science of mind is not. It has recently gone through stages where the major foci of study were the philosophy of mind, introspectionist and then behavioural psychology, and cognitive psychology. It is in this science of mind tradition that many of us, including the present

author, are working; for the moment, we are content to call ourselves " Cognitive Scientists." (It is to be hoped that we can widen the terms of reference of the field to the point that Searle and Edelman can enter. Indeed, Searle suggests that his new neurophysiological/phenomenological field should be called "Cognitive Science." Consequently, in contrast to the iconoclastic Edelman, he is a reformer.)

For Von Eckardt (p. 15) is proposing that Cognitive Science be considered "an approach to the study of Mind" with no expressed limitations. These enter only when she is outlining the metaphysical and methodological premises of her discipline. Suddenly, Mind becomes "the human cognitive mind/brain" (p. 50) which consists of a set of cognitive faculties, for methodological purposes best considered as absolutely distinct from each other; the same purposes will require the exclusion of Consciousness, affect and social factors. It need not be emphasized that we have now left the study of mind; the field being described so thoroughly could perhaps be described as computational psychology. All the more so, since the two central assumptions are computationalism and representationalism. The functionalist ethos of modern mind science with its insistence of multiple realizability of mental process also permeates her discussion. The discussion of representationalism is superb (p. 143ff) and the introduction of different types of representation via Pierce's distinction between index, sign and symbol may save the concept from attacks such as those of Stich. However, the tension between Cognitive Science as the science of mind and as something rather less has not been relaxed, nor will it be by Von Eckardt.

Whether deliberately or not, Von Eckardt does us a service by pressing the attack on this point. She refuses to allow its domain be simply propositional attitudes, as Fodor would prefer (p. 65); Pylyshyn's *ne plus ultra* for the discipline is identified as unencapsulated faculties, before being rejected as too confining. However, her own analysis would suggest that the current de facto limitations of Cognitive Science will not allow it to handle many phenomena causative in human cognition; she has little more than aspirations to offer on that score. Finally, her analysis suffers from its complete ignoring of the Anthropological component of Cognitive Science, and the lack of detail on several of the other disciplines constituent of Cognitive Science. The constraints she sees Neuroscience imposing on Cognitive Science are strong (p. 330); yet she refrains from referring to Edelman's conclusions, as noted above.

Von Eckardt, then, has out-Searled Searle in her criticism of Cognitive Science. An alternative path to constructing a foundation for Cognitive Science, and the one this author has taken, is first to review those disciplines which claim any province of the science of mind. Common themes, when they emerge, allow the construction of a common language as Halley (1992, p. 1) advocates, rather than its imposition, *de haut en bas*.

Consequently, then, AI has exerted an ambivalent influence on CS. It gave the area its initial impetus, but biased its research toward representationalism to the exclusion of many relevant formative influences on cognition. Moreover, the pronouncements of brilliant AI researchers on philosophical issues have often demeaned both themselves and the topics on which they're holding forth. Perhaps the most subtly malign issue, however, is the exile of the mind from world implicit in the computational metaphor.

The anti-environmentalist consequences I have discussed elsewhere (Nolan, 1992): even in engineering terms, as the brilliant work of Brooks (1991) has indicated, the metaphor seems incorrect.

In fact, CS has doomed itself to failure as a coherent science even of cognition by this exile. The very structure of the nervous system has been formed by organism/environment interaction, constraining the nature of the computations which can take place (chapter 4). Language considered as a closed system is inscrutable; considered as a channel of interaction with the world, it reveals many of its secrets (chapter 3). Perception is the hopeless analysis of a chaos of shifting impressions, until we take into account the mutual influences of organism and environment (chapter 2). In chapter 1, we discussed the philosophical absurdities which arise from separating mind and world: there are more such to follow in the next chapter.

Mind, then, is not a set of algorithms, nor any such box of tricks: it is, however, visible in the ordering principles manifest in adaptation over time. With increase in the organism's computational powers, those principles become more informationally complex. Yet we cannot understand this complexity in terms of the computations alone: we must find ways of characterizing the environment correctly. I have discussed the notion of "context" as one such characterization in chapter 2 and 3 and shall continue the line of argument in chapter 7: Gibson's notions such as "affordance" and "optic flow" have a similar intent. These characterizations might yield a more intellectually correct as well as a more technically accomplished Cognitive Science. Let's now summarize the viewpoint of this book before focusing on the techniques of AI.

1. We explored the current debate about the domain and methodology of Cognitive Science and found a tension between the received foundations and current Science of Mind ambitions of the discipline. The tension is exacerbated by critics who fault the subject for its reluctance to address consciousness, affect and social factors and in so doing elevate itself in accordance with its current ambitions.
2. The viewpoint taken here is that addressing these issues still allows a coherent discipline to exist. Social factors can be handled by informational characterization of subject-environment relations (as done in, for example, situation semantics), affect by studying its informational role, and consciousness by examining projection of informational distinctions (see chapter 8).
3. These moves extend the discipline as required, while also allowing it a neat demarcation line from other disciplines. It can act as a reservoir of interdisciplinary knowledge while accepting that, for example, the analysis of social trends (as distinct from how they are processed by the individual) is not within its scope; likewise, those aspects of applied experimentalism dealt with in consciousness studies are not informationally salient in a way we can currently characterize and so not now within its own remit. The manufacture of those new tools for thought and action called "cognitive artifacts" is an engineering problem; the issue of their fit with human needs and abilities is an applied cognitive science issue.

4. At an individual level, several distinctions (e.g. egocentric versus intersubjective), arise naturally in the analysis of cognition, as does the notion of the importance of the Lifeworld, etc.
5. At a guess, the core subjects of cognitive science will remain cognitive psychology and those aspects of philosophy, anthropology, neuroscience, ethology, AI and linguistics which have specifically cognitive reference. They will remain in competition with each other in the sense that at any time only one of them will be perceived as having most promise.

Perhaps a term such as "Noetic Science" (inspired by the Greek term for knowing) might better capture the interdisciplinary attempt to study the mental in so broad a context. At a guess, however, we're stuck with "Cognitive Science" as a term just as we were with AI.

5.2 Skeptics and their techniques

Figure 5.0 features unflattering and often wholly inaccurate depictions of our skeptics.

5.2.1 Ludwig Wittgenstein and Slot-Assertions

Wittgenstein we have already met in chapter 1. His life he described himself, while dying of cancer, as "wonderful" and I take his word for it. What is certain is that it was exceptional even in the company of the many other eccentrics here in the Hall of Skeptics. He was born in Vienna in 1889, a scion of one of the wealthiest families in Europe: having given away his vast inheritance in his early thirties, he spent the latter part of his life as almost an intellectual vagrant, at one point asking (and being refused) permission to live with a Connemara peasant's family. Intellectually, he was in turn an aeronautical engineer, a mathematical logician, a general semantician, and an all-purpose iconoclast: his careers were successively those of a professional philosopher, a much-decorated infantry soldier in the Austrian Army, a professor of philosophy (in his PhD exam, his Tractatus was described as a work of genius, and thus certainly adequate for the award), a hospital orderly, a spurned would-be medical student in Dublin, and an intellectual dharma bum. (Monk, 1990, provides a superb account of his life and work. Derek Jarman's film is both instructive and moving.) Like Alan Turing, he was homosexual, or whatever the politically correct word is at the time of reading. Either through guilt or lack of interest, he remained mainly chaste.

Wittgenstein's lifelong obsession, we learned in chapter 1, was language and its relationship to the world. Like all of us, he wondered whether there was an order in the world a priori, or whether we imposed order on it. That his philosophical scholarship was rather poor (Kant's response to this question we have already noted) was an advantage in this case: the naivety led to a sense of adventure, and the *Tractatus* took the philosophical world by storm. We have already viewed logical atomism as Computer Science per se, and in the immediately preceding section as Cog Sci: what remains for us to do now is to view it as AI, or more particularly as NLP. It may not be altogether fair to Wittgenstein to extend the scope of logical atomism beyond language: it is a theory of language's relationship to the world.

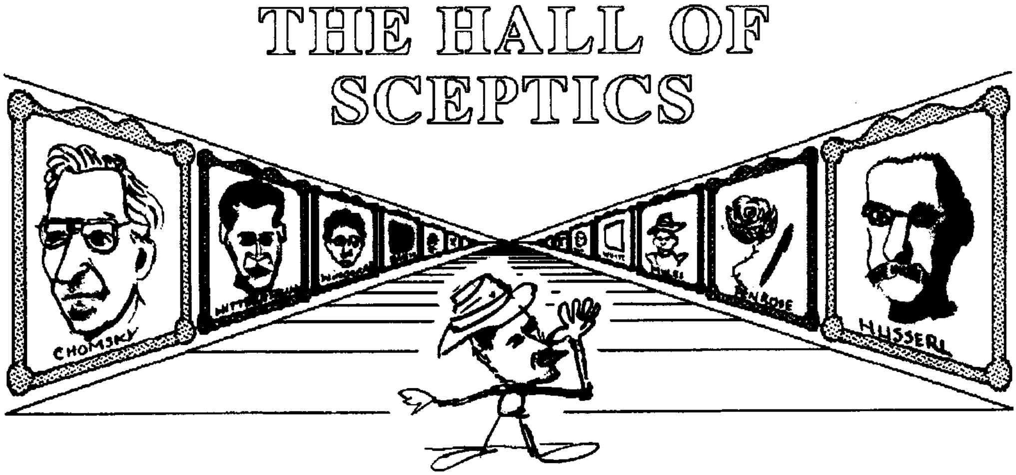


Figure 5.1

Schank (1977) we have already remarked on as an unconscious disciple of the early Wittgenstein. In its pristine form, Conceptual Dependency (CD) attempted to map all of language onto the following main verbs, which we've mentioned in chapter 3: PTrans, MTrans, ATrans, Propel, Mbuild, which could have their purposes achieved by the action of the subsidiary verbs: Attend (i.e. focus on), Speak (make noise), Move, Grasp, Ingest and Expel (the latter two are generic terms for actions performed to and by anything animate). The use of these verbs, we noted, can effect changes on states of health, anticipation and awareness. Even this minimalist approach has hidden layers of complexity. Schank and his followers outlined what it meant in terms of them for item A to cause item B, and a multitude of other relations. The resulting NLP systems, as we've noted, were capable of paraphrase and translating sentences like

Der Rat verabscheidet den Beschluss.

to

The Council adopted the resolution.

if the CD "requests" which mapped the verbs onto CD primitives were worked out at length and mappings set up between the nouns. That of course is quite computationally expensive, and to set it up to translate our old friend (chapter 3):

Johann nahm die Torte von der Tisch und er putzte ihn.
John took the cake from the table and washed it.

involves a completely separate language-engineering task.

Nor was Schank's the only such Tractatus-type attempt. Sergei Nirenburg (et al, 1991) has produced a number of similar systems. Interlingua is the Holy Grail of NLP.

Were an adequate interlingua to be found, the task of intertranslating the world's 3000 languages would be simplified to writing 3000 parsers to map the source languages to the interlingua, and 3000 generators to map from it. The truth is that, because of the inadequacy of logical atomism, we're more likely to have to specialize the mapping from each source language *i* to each target language *j*, with N the number of languages, resulting in a number of programs calculated by $N^2 = 9{,}000{,}000$

Moreover, the addition of semantic primitives to this latter type of "transfer-based" system is a mixed blessing as many MT systems have found.

None of this would have surprised our Ludwig, who began to attack formalization (even of mathematics, let alone language!) with the zeal of a convert. In fact, like many of his equally technically brilliant companions in our hall of skeptics, Wittgenstein inveighed strongly against what he saw as the dehumanizing effect of science's effort after general laws. This should give us pause: Chomsky spends most of his time campaigning tirelessly for the violently politically oppressed; Gödel and Penrose are Platonists; Turing was convinced of the reality of telepathy; Husserl sought a science of transcendental self; Winograd directed a society for responsible computer professionals, concerned inter alia that trigger-happy expert systems should not make the final decisions about starting WW3. Indeed, it does rather seem that the malign features of Computer Science cannot be blamed on its true founders. The truly reductionist seem to be divided roughly between the eschatologically (awaiting the end, like David Koresh!) reductionist (Minsky grew up in a community which saw itself as descendants of Rabbi Loev, who famously was reputed to have attempted to build the first robot, or Golem), those technically incompetent philosophers who saw AI as a chance to make provocative statements, and fine AI writers such as Tanimoto (1990, p. 6) who are cheesed off with the redundant philosophers of the first section in this chapter.

Wittgenstein was part logician and part mystic in his early work. His later comments on language centered on the doctrine of language-games, i.e. inventing imaginary situations in which language is used for a tight practical purpose. In these language-games, the activities and reactions are clear-cut and transparent. These might include a construction worker shouting "Slab" to indicate "Give me a slab!" Again, let's note that context has obviated syntax and semantics: the lexicon is feeding straight into the pragmatic level. For logical atomism's analysis, the later Wittgenstein substituted conceptual investigation as the analysis of words such as "intention" and "will."

The later Schank showed a similar realism. His "scripts" refuse to try and separate form and content *à la maniere de* his early work. Chapter 3 features a script for a myth such as that of Diarmuid and Grainne. AI "naive physics" research focuses on precisely what primitives are relevant for particular contexts, and which primitives are context-general. I have done some preliminary work on this problem. Such concepts as "animate," "gender," "location," "event" are utterly general; however, "composite" and "unitary" are far less general. Finally the kinds of distinctions which might underlie the conversation of e.g. two expert computer programmers without needing any explanation (that function's a kludge) are less general still (see figure 3.16).

With Wittgenstein, therefore, we become au fait with the logical atomist approach to KR and the problems thereof. Essentially, we have to decide for ourselves which logical atoms are appropriate for which applications without being able to appeal to any general laws. Our next skeptic, Edmund Husserl, is going to lead us to the same destination via an interesting object-attribute-value (OAV) route. Wittgenstein's KR we can, by contrast, describe as slot-assertion (SA) or predicate notation. In formal terms, OAV can actually be described by SA Predicates, and (to spoil the story) shares its formal limitations along with its epistemological limitations as we shall now see.

5.2.2 Edmund Husserl and frames

Edmund Husserl was born in Proswitz in 1859 and died in Freiburg in 1938. Husserl, according to victor's history, was supplanted in his chair at Freiburg by Heidegger after the latter's opportunistic joining the Nazi party, a move which led him eventually to the Rectorship at Freiburg. As usual, the story is more complex: whatever about Heidegger's motives, the early Husserl was, like the early Schoenberg, a fervent German chauvinist as well. I have discouraged my illustrator from doing amusing drawings on this subject.

In chapter 1, we followed Edmund's career through its early psychologism to the latter phenomenology leading to his interest in the transcendent. Of most importance for us is the phenomenological stage. For Husserl, one of the major issues in this discipline was that mental representations of any type of object had to provide a set of expectations (i.e. a context) for structuring incoming data. If expecting a car to be the next object, we expect that it will have certain default attributes e.g. an internal combustion engine, four wheels, doors. These default assignments Husserl called the "predelineations": the object at the top level he expected to be invariably the same, even if certain of the default assignments turned out incorrect (an invalid's three-wheeled vehicle is still a car). For Husserl, the beliefs expressed in the predelineations in their relationship to the facts defined the context.

Now we come to the sad part. How many such contexts are there? Grey, blue, electric, BMW…? Husserl's rueful final comment was that he was a perpetual beginner in phenomenology. The multiplicity of these "contexts" (we use the term differently) and the impossibility of predicting which one was next together constitute the most pathological manifestation of the Frame Problem.

By coincidence, the Husserlian object can be captured neatly in OAV. We expect a car (Car1) to have the following profile:

(Car 1 County of manufacture Japan)
(Car 1 Color Brown)

Note the consistent object-attribute-value sequence. The top level object is "Car": the OAV notation captures everything we need to know about it. Our default assignments allows us to predict certain stable features about cars: they are likely to have four wheels, and less likely to be manufactured in Japan, which means that "4 wheels" is a worthwhile default assignment. However, to try and calculate all the defaults which

are likely to be necessary from moment to moment is a horrendous task computationally. The Frame Problem rears its head once again.

In fact, OAV can be described in Predicate Calculus (PC) if the separate propositions in PC can be interrelated, for example:

(Color Brown)
(Number-of-wheels 4)

can all be housed under a data structure called "Car." The problems with logical atomism and these with OAV have the same origin (aetiology). In fact, that supposedly higher-level KR systems such as Frames (and their near relative semantic nets) can be described in PC means they all have the same problems. Wilensky (1987) comments on this and adduces the following desiderata for KR systems:

1. They should be capable of mapping any domain (i.e. be epistemologically adequate).
2. Each construct of the KR system should have a direct referent in the world (denotation).
3. If possible, the KR system should be uniform at the epistemological as well as the algorithmic level across all domains. This will lead to economy of processing. Unfortunately, this is a pipe dream. Syntactic regularity can give semantic relationship only in very restricted contexts. Wilensky proposed that his millenniar system should work for everything.
4. Psychological Plausibility. Thus, any system dependent on Modus Tollens better beware!

Wilensky proposed the banner heading "Cognitive Representation Theory" (CRT) and KODIAK as a system conforming to principles i-iv. Unfortunately, the number of concepts in a CRT system will, by Wilensky's own admission, exceed the number of words in the text (see chapter 3). There seems to be no escape.

We humans manage to line up a myriad hypotheses at various levels and Nature has gifted us a Computational architecture which sees their confirmation or not all simultaneously processed. The attempt to emulate this computationally runs slap bang into the Frame problem. Even the act of processing a simple sentence has hidden pitfalls. If there exist two possible parses for a sentence (and usually there are many more), in the absence of a neat semantic routine allowing instantaneous disambiguation the parser must search through many possible parse trees. This search problem achieves pathological proportion when, for example, the travelling salesman tries to plot an optimal route through 100 different cities. AI has developed many routines to ameliorate search: it helps greatly if there is a readily-calculated estimate of distance from the goal state at all points.

There was a time in AI when GPS-type architectures in conjunction with search routines defined almost the whole discipline. Recently, genetic algorithms which view tentatively proposed solutions as the attempt of a generation to reproduce have come

very much to the fore. Again, we depend greatly on an evaluation function, continually calculable over the whole search space.

We leave Edmund in his later career, attempting to view his experience in terms of a transcendent self experiencing transcendent objects. It is time to hurry onward to the homosexual father of computing.

5.2.3 Alan Turing and Computability

Turing is credited with assisting in breaking the Enigma codes during WW2. Again, let us beware of victor's history: the Enigma codes, a commercial venture of the 1920s were actually decrypted in the early 1930s in Germany by a commercial rival and their adoption even in elaborated form by the Nazis is something of a mystery (I promise that this is the last mention of the Nazis, who seem to be cropping up everywhere in this book). Alan Turing, Emil Post and Alonzo Church all achieved their initial fame by proposing solutions to Hilbert's *Entscheidungsproblem* (roughly translated, the decision problem). To understand Turing, Post, Church and more importantly computing and its limitations, it behooves us to concern ourselves with Hilbert.

In the early years of this century, Hilbert challenged his peers to determine whether there existed a generally effective mathematical procedure, i.e. an algorithm which could solve everything from NLP problems to differential equations to calculating a payroll. If it existed, a formal device (i.e. a computer) embodying this procedure would solve every problem. (Historically, the Sufi mystic Ramon Luil, the Franciscan Roger Bacon and the philosopher Leibniz dreamt of the same thing). Think about it! It must be pretty content-free: if it embodies any considerations relevant to e.g. differentiation, it has ruled itself out of court, for everything else: it must be pretty powerful, and yet reasonably simple. We can never prove that it's precisely correct: the "proof" of the Turing-Church conjecture is that any opposing views have been established as formally identical. In fact, the wild surface differences between Turing's and Church's formulations conceal their formal identity: this has led Penrose, inter alia, to propose that computability is a Platonic Form.

Turing's solution resembles Emil Post's. Computing, he argued, can be conceived in terms of the following components:

1. An infinite tape (yes, beyond the rings of Saturn, as in diagram 5.1).
2. A read head to read a program of instructions.
3. A write head capable of rewriting 1 as 0, 0 as 1.
4. An automaton which can move the tape.

We can also allow the Turing Machine (TM) to stand up, as in the diagram in the title-page of this chapter. Amazingly, a TM can be constructed to calculate any mathematical function, given sufficient supplies of time and masochism.

Is there a solution to the *Entscheidungsproblem*? On the contrary: what Turing established was that given any arbitrary TM (N) with input (M), it could not be established whether the TM would ever halt or not. (Cantor, who created the diagonal slash argument which Turing used, went insane; Turing committed suicide. I leave Turing's proof as an exercise for the reader.) Consequently, there exists no generally

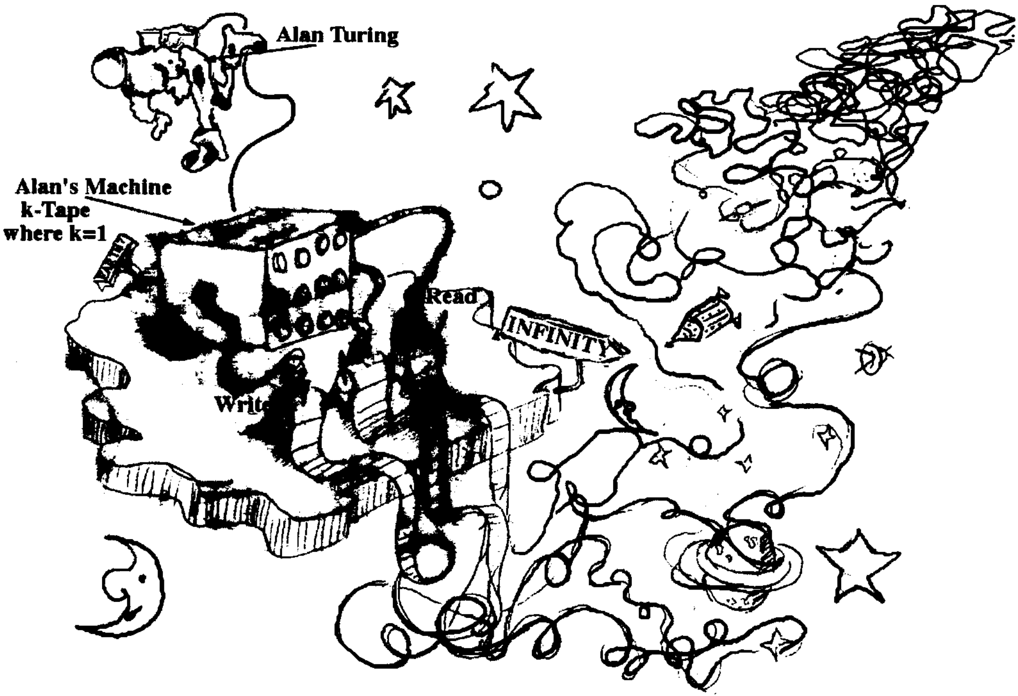


Figure 5.2

effective mathematical procedure. Yet hope springs eternal: we can still construct a Universal TM (UTM) which can simulate the operations of any individual TM. It is stretching matters only a little to see the UTM as a computer and the TM as a program running on the computer. Turing's result indicates that there may exist problems which are not solvable in finite time.

Let us recall chapter 3.An efficient NL parser was capable of O (N^3), where N is the number of words in the sentence i.e. the time taken to parse was proportional to the cube of N. In like vein, we can talk of (P) problems soluble in polynomial time (N^K), (NP) i.e. non-polynomial, and NP-complete which may be more difficult still. Many NLP problems are NP-complete.

Astonishingly, the connection between TMs and language cuts even deeper. We can regard the acceptance of a language by a grammar as the possibility of solution of a problem in finite time. (Some interesting results indicate that there is no guarantee we can learn a Type 1 grammar). We can speak of P, NP and NP-complete languages, all of which are encoded in TM formalism. Moreover, we can establish that it can't be proven that any randomly chosen Type 1 language can be recognized in finite time (another exercise for the reader). If an extra-terrestrial should talk, we might not understand him: his language could be Type 1.

Finally, to end this section with some light entertainment, here is the Turing test described implicitly in the discussion of Searle in chapter 1. Well-trained Dublin barmen don't even see their customers. If Myles and friend are judged identical over 50% of the time, we can, as diagram 5.3 suggests, assume they're running the same program. **Here too Turing was pessimistic, allowing that even by the year 2000 he doubted the test would be passed.**

5.2.4 Gödel, completeness and decidability

Kurt Gödel was born in Brünn, Austria-Hungary, in 1906 and adopted American citizenship in 1948. He's dead. He is actually responsible for the breakdown of formalist Mathematics and we refer to him again in chapter 8.

Turing-decidability is the property that any proposition produced by a PC-type system should be provable as a valid theorem of the system or not. PC is in fact semi-decidable: we can establish that we can prove that any theorem is a theorem, but not that a non-theorem is such. Yes, I've thrown you into the deep end of Gödel's work, which directly echoes Turing's. Gödel's fame arose from his demonstrating the following about any system with at least the formal power of arithmetic:

1. It cannot demonstrate its own consistency
2. It will contain propositions which can neither be proven nor disproved in its own formal machinery.

Reasoning as numerical calculation therefore has formal limits, the transcendence of which limits we'll see that Penrose equates with the emergence of consciousness (see

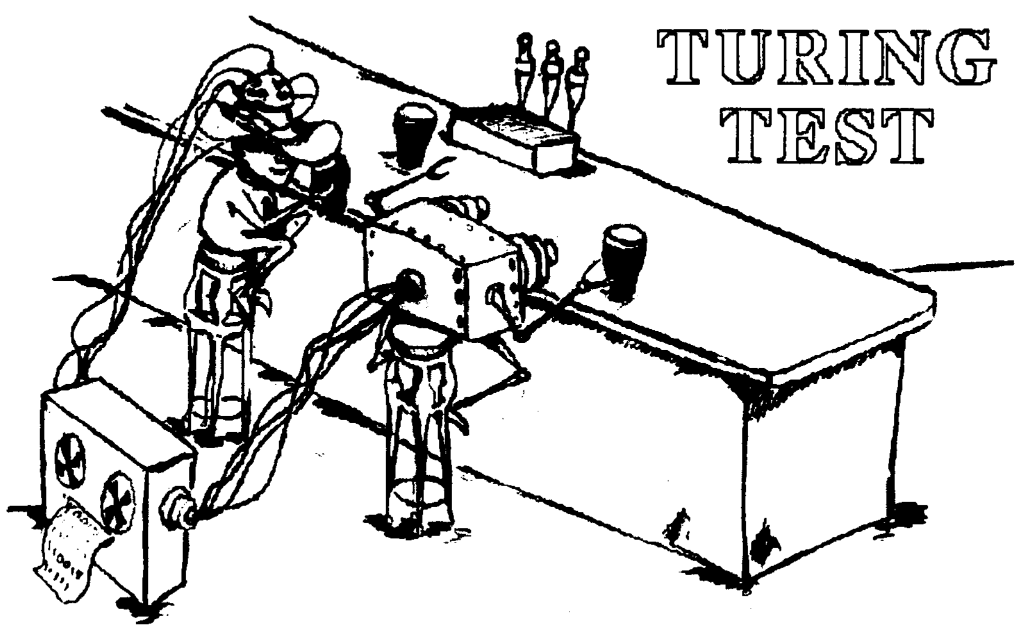


Figure 5.3

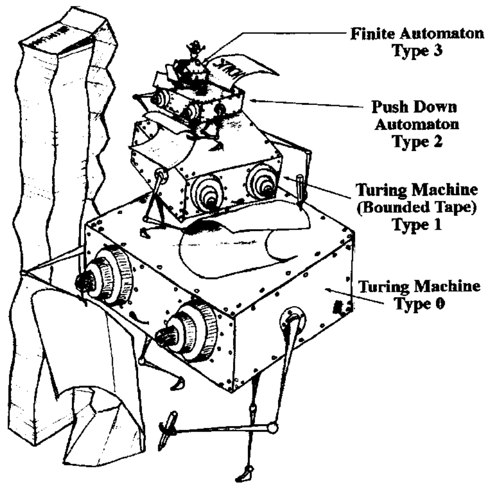


Figure 5.4

chapter 8). We can interpret Gödel's result as an implicit criticism of systems such as SOAR (Partridge, 1991, pp. 437–443) which in any case have huge KR difficulties. Gödel established that the set of recursive functions is calculable: in that he echoes the Turing-Church thesis. Techniques exist to convert mathematical problems into pure or partially recursive form. We've met recursion already in chapter 3, along with Noam Chomsky, our next skeptic.

5.2.5 The Chomsky Hierarchy

Recall the classification of Grammars in chapter 3? Well, you've read the book, here's the diagram (5.4). You will recognize the bottom level, the TM, which turns out to be precisely formally equivalent to a Chomsky Type Grammar. Our former Type 0 and Type 1 are both now regarded as Type 0. Context-sensitive, Type 1 Grammars, feature a finite tape with read and write heads; Type 2 or context-free grammars have a stack, a computational device allowing recursion and a read head; Type 3 can be implemented simply as a regular grammar. We have remarked that all natural languages fall somewhere between Type 2 and Type 1. In fact, another abstract system called an indexed grammar can parsimoniously handle all NL expressions.

Why is Chomsky a skeptic? Again, because of his insistence that language is unique (sui generis), the unfolding of the LAD. We have already discussed the shortcomings in Chomsky's theory. Obviously, this skepticism is even more true of Fodor, who sees all cognition solely in terms of the unfolding of an innate language of thought.

5.2.6 Roger Penrose and the last Emperor

Penrose's (1989) book at a stroke followed Searle's (1980) article into the nether regions (*anus mundi*) of AI infamy. Frankly, it is in this reaction (e.g. Sloman, 1992) that AI begins to show some hypersensitive colors. We'll meet Penrose again in chapter 8 as a wholly inadequate theorist of consciousness. His book is an attack not on the discipline of AI, but on the intellectual position called "AI" which he identifies as the unreconstructed proposal that computers can have mental states. His book is a brilliant attack on a straw man. On completing it, you will have a firm grasp on the main principles of computability, quantum mechanics, cosmogony, algorithms, neuroscience, non-recursive mathematics, set theory and neuroscience, without really knowing why.

Penrose as skeptic is discussed in chapter 8. As creative theorist, he brings our arguments about the identity of language recognition and computational complexity a few stages further. He proves that we can justifiably bring in set theory as well.

Algorithms generate recursive sets, the recognition of which is in general possible. Non-recursive sets seem the province of conscious experience. Moreover, these non-recursive sets (particularly those which are recursively enumerable) describe the physical neurophysiological processes which are occurring in conscious experience. Indeed, Penrose regards his own (non-recursive) tiling theory as a valid theory also of how conscious experience "tiles" new neural pathways in the nervous system. Most physical processes are straightforwardly algorithmic: Penrose argues that because of its meta-Gödelian nature (see chapter 8), conscious experience must transcend this. He will not allow that computers are conscious: only at least a half-brain can be. With Penrose's nevertheless brilliant book, we find an extraordinary confluence of themes from mathematics, neuroscience and physics. His more recent work is influenced by the conjectured possibility of coherent quantum states in the "cytoskeleton" of cells.

5.2.7 Terry Winograd

SHRDLU are, respectively, the seventh to twelfth most commonly used letters in English and is the title of Winograd's (1972) early system. It involved a simulation of a robot arm on screen shifting blocks around in accordance with NL instructions. Frankly, apart from the neat Prolog-like planning of actions, little distinguishes the NLP from the ATTs described in chapter 3.The context is so restricted that the syntax, semantics and pragmatics are inextricable.

Yet SHRDLU was an outstanding technical advance in its demonstrating that NLP was possible in that kind of microworld. Winograd et al's (1986) later work was outstanding for fully acknowledging that microworld principles would not generalize.

In fact, the catch-cries of situatedness and embodiment have yet to be both reflected in Winograd's technical work: for that, we must refer to Brooks (1991). Brooks couples organism and environment by implementing robots which are minimally pre-programmed, being directed only to explore. Their computational architecture features embedding of finite state automaton (FSA) (see regular Type 3 grammars) one within the other. Ideally, a Brooks creature has sensors, FSAs power supply and minimal program all on board.

They have had outstanding success in solving the perceptuo/motor frame problem we first referred to in Berkeley by means of egocentric knowledge, built up by active interaction with the environment. Brooks, however, goes too far in stating that symbolic action, consciousness and intelligence will emerge inevitably for reasons the chapter 1 discussion of Merleau-Ponty made clear.

5.2.8 Bayes and Probabilistic Reasoning

Being the last will and testament of the Right Reverend Thomas Bayes, born in the year of Our Lord 1702 in London and recently deceased in Tunbridge Wells, 1761:

"I labored a lifelong with mathematics, that I may establish first the truth of Isaac Newton's calculus, and the divinity of Christ. Being able to maintain myself by my clergyman position as a secure English nonconformist, I thought with myself that I should better myself through the hand of God as manifest in chance. I declare to my God that I resolved that the probability of event a given the occurrence of event b

equalled the probability of a (a priori) multiplied by the sundry probabilities of b given a divided by the probability of b (a priori).

$$P(a/b) = \frac{P(a)\,P(b/a)}{P(b)}$$

— Disgusted, Tunbridge Wells"

In fact, Bayesian probability is very much back in fashion, particularly in NLP where all else seems to have succeeded only slightly, and within NLP particularly in speech to text applications. Let us consider the task as that of mapping a phonemes b,… bn onto text a,… an. We need to establish:

1. The relative probability of occurrence of text items P(a).
2. The language model as described by P (b/a).
3. The relative frequencies of $b_1 \ldots b_n$.

That established, we can ignore syntax, semantics, pragmatics (in fact NLP in general) and look on the problem as purely an engineering one. This has been done with remarkable success, for example in military (DARPA) projects. A similar approach might be used for MT, i.e. simply regard translation as inter-mapping of words occurring with identical frequencies in source and target texts. Finally, it has been found that one need only take into account frequencies of patterns involving 3 words at a time (trigram model) for optimal use of this approach.

Bayes' work in probability theory has been the subject of numerous attacks, which is why he merits inclusion in this section. However, it seems to work well, whatever its theoretical shortcomings.

5.2.9 David Marr and the syntax of vision

Marr's work involving a primal sketch of the syntax of the scene is well-described in Partridge (1991). For Marr vision was above all algorithmic, yet he insisted that a deeper level of analysis than his was necessary. Once we go deeper, by for example including the types of KR in 5.2.1 and 5.2.2, we abandon generality for power. We shall notice this trend in expert systems as we already have in NLP.

5.2.10 Myles and Post-Modernism

Post-modern novels allow the narrator to write about a character who writes about the narrator. We find ourselves in a strange loop or tangled hierarchy (Hofstadter 1979) (see diagram 5.5). The link with Gödel should be clear. Let's note that our waking up from one level of recursion is, according to Penrose, the epitome of a conscious act.

In his incarnation as Flann O'Brien (1939), Myles wrote the first fully-realized post-modern novel. It becomes difficult at times to tell who is narrating, and the characters are allowed to plot against the life of Trellis, the original narrator, whose life is saved by the accidental destruction of the manuscript by his maid. In the Gödelian framework, we can regard the tale narrated by one of Trellis's characters as one system. Trellis's tale is the most encompassing system. Decisions on the truth or otherwise of a particular segment of narrative, or from whom it originates, would fall under the

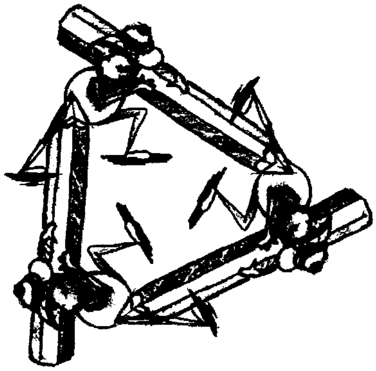


Figure 5.5

category of processes which Penrose suggests is non-algorithmic.

5.2.11 What would Descartes think of being called a skeptic?

Another exercise for the reader. Hint: how can res cogitans affect res extensa? And how could this possibly be implemented?

5.3 AI as Computer Science

In his superb IJCAI Computers and Thought lecture, Rodney Brooks (1991) comments on several aspects of conventional computer architecture:

1. He conjectures that alternatives must be considered e.g. protein folding. If a protein is deformed from its standard configuration, it automatically regains it, often in a matter of seconds. This reforming procedure is massively informationally rich, and might support the kinds of process necessary for cognition.
2. He comments that computing involves an extremely fast processor operating over a very narrow band width with a large, almost wholly inactive memory. We saw in chapter 4 that the brain differs on all of these points.

Parallelism is currently very much on the agenda for AI as computer science: however, the comments which Brooks makes are perhaps deeper. His epistemological emphasis is very much on situatedness and embodiment. Yet again, I wish to flag the following limitations in robotics qua epistemology:

1. It is over-sanguine to expect consciousness simply to emerge.
2. Fully symbolic behaviour must be supported by a specific architecture.
   Chapter 7 reveals the goods on these particular issues.

We have just glanced at objections by Turing, Gödel and Penrose to AI on the grounds that its programs are formal systems and necessarily incomplete. Moreover, in Penrose we find that this incompleteness relates to AI programs being supported by physical processes which are, in his definitions of these terms as noted in 5.2.6, "algorithmic" and thus "computable." One alternative suggested is the "quantum computer": a computer based on only partly deterministic physical processes. It has been conjectured with some credibility (Penrose, 1989, pp. 518–9) that these computers can theoretically reduce NP-complete problems to P in some cases.

5.4 AI as software

The theme of this section is that it is possible to plumb either for syntactic-level generality or KR level power, but one must be sacrificed for the other. Moreover, the use of probabilistic reasoning seems to help greatly. Development of the area awaits advances in machine learning which seem a little over the horizon at this stage: I refer

the reader to Partridge's (1991) excellent analysis both of this topic and the specifics of the AI systems which I discuss only at the most general level.

In 5.6 we consider the notions of context, syntax and semantics in AI.

5.4.1 NLP

We have looked at length at NLP qua Computational Linguistics. As AI, we've seen that the turning-point was Winograd's SHRDLU, which established that

1. Success was possible for NLP in a restricted context
2. However, this context was a "micro-world" and it became obvious that it was a formidable task to develop context-general principles

So the situation remains. The algorithms have become more efficient (Tomita, 1986); the applications include NL interfaces of increasing coverage (Hendrix, 1987) and interlingua-based machine translation systems of ever greater sophistication (Nirenburg et al, 1987). Yet even these successful systems remain tied to specific domains and there does not seem to be any principled ways of fitting a system to a domain; much is left to ad hoc improvisation and trial-and-error.

In fact, the state-of-the-art in NLP can be summarized quite neatly:

1. Where language needs to be considered only on the syntactic level, the task of building a parser seems straightforward (e.g. for grammar-checking). If the context is restricted sufficiently to allow conveyance of semantic relations by refined syntactic formula (e.g. data-base interface), the requisite system can be created. However, that system will include much that is domain-dependent.
2. If the context is less restricted than this, the domain may be mapped by semantic primitives. Yet again, the semantic primitives selected will contain several which are domain-dependent (Schank et al, 1977).
3. When the text understanding requires speech-act sensitivity i.e. a knowledge of the speaker's intent, a less-than-graceful degradation of performance occurs (Winograd, 1990). It is proving very difficult to handle context change.

In summary, then, NLP systems work well if the domain can be mapped syntactically, and second-generation systems work with semantic representations within specific domains. As yet, no principled methodology exists for moving between domains, nor for handling speech-acts.

5.4.2 Expert Systems

Expert Systems remain AI's major success story and thus require little introduction. Again, it is appropriate to distinguish between:

1. Systems which map the domain at a syntactic level. This is quite sufficient for rule-book applications (Feigenbaum et al, 1983)
2. Systems which attempt representation by structured object representations e.g. the graph theory application in Internist and Prospector's inference networks (Duda et al, 1984).

3. The intractable problem of context-independent systems which map all possible domains at a fundamental level.

The more successful expert systems use a combination of structured objects and probabilistic reasoning with, as in Robotics, a recent focus on fuzzy logic (I'm 40% sure of that).

5.4.3 Vision

The situation for vision is neatly summarized by Tanimoto (1990):

> "A computer system has not yet been created which can look at an image and describe the scene depicted" (p. 410).

That goes even for static images. Movement has proven even more difficult to handle (Thompson et al, 1990). Again, we can distinguish between

1. A description, such as Marr's "primal sketch" notion of the "syntax" of the scene, which has proven to be a tractable problem.
2. The much more difficult task of scene description (Tanimoto, op cit).
3. The currently intractable problem of movement. Indeed, the focus of Computer Vision was up to recently the reconstruction of a presumed static external world. Where it has been informed by Gibson, it has progressed quite quickly.

5.4.4 The Frame Problem

We have frequently met the Frame Problem in the course of this book. Let's encounter it now at home in AI.

Pylyshyn (1987) identifies the frame problem with the problem of relevance: "This, the problem of relevance, is what many believe lies at the heart of the frame problem" (Introduction, p. *x*). Hayes (1987) in the same volume, indicates its aetiology: "The frame problem arises when the reasoner is thinking about a changing, dynamic world, one with actions and events in it" (p. 124). Essentially, it relates to the processing of change by a system based on updating of representations for handling change. No principled methods exist of determining what is relevant or otherwise in any change which occurs.

In essence, the frame problem is inescapable for any representationalist system, and it is as well to stress this point now. In fact, if we broaden the concept of "change" to include on the one hand change of domain for expert systems and NLP, and on the other movement for vision systems and change of speaker for speech-recognition systems, then the frame problem acquires a new, disturbing life. It then seems to reflect a much more fundamental difference between human cognition and AI than hitherto suspected: in fact, it threatens the representationalist paradigm as a good model for the one, and as a technical apparatus for the other.

Some within the connectionist community have argued that theirs is a new paradigm for AI: "The upshot of this is that connectionism provides a kind of Copernican revolution in cognitive explanation. Instead of having the running system

revolve around an antecedent analysis of the task, we may make the analysis of the task revolve around an up and running system (Clark et al, 1990, p. 12). The domain will map itself onto the system by a "continued process of analysis" (ibid). Gardner (1985) commented on the closeness to Gibson's system of PDP (pp. 321–2) but wisely refrained from taking sides on the issue of whether connectionism can provide a new framework for AI. It is only the more unconventional, non back-propagation learning algorithms which might have anything to say on this score.

5.4.5 PDP as AI

The initial auguries are unpropitious: "Although the current generation of networks appears to be very good at performing/learning to do what are essentially static/spatial tasks, there has been relatively little progress on networks that can cope adequately with tasks which have an important temporal/sequential component to them" (Clark et al, 1990, p. 11). Perhaps PDP can in the future evade the frame problem; at present, such is not the case for the standard models.

In all, the successes of PDP in pattern-recognition and cognitive veracity must be set against the current failures as software for example the domain-dependence of these systems.

5.4.6 Summary

We are left with the following picture of AI:

1. Many ingenious methods have been developed to treat various domains at a syntactic level for the modalities of speech and vision, and for reasoning.
2. Where a real-world application for a specific domain is required, the mapping always involves considerations relevant only to that domain.
3. No principled way has yet been found of handling domain change.

5.4.7 The recent history of AI

We have rarely stained our hands with commerce in this book, but may as well look briefly at market trends for AI as software. We've also mainly been concerned with how AI software works in terms of the categorization above; let's broaden things a little. Many 1980s startup companies folded, and the projected market for Lisp machines evaporated when it proved more cost-effective simply to use Lisp on the by now much faster PCs. To complicate matters further, much AI technology remains hidden in conventional software products; word processors may include grammar checkers, and even Cobol now has an object-oriented version. It is thus really difficult to gauge the size of the AI market. Automation of knowledge in its various forms may become a commercially hot issue soon, and AI may explicitly be in demand again. At the moment, we are in the paradoxical situation that many non-AI techniques (such as statistical reasoning in case-based reasoning products, which attempt to derive conclusions on previous elaborated cases) are used in explicitly "AI" products, and conventional software uses AI techniques.

As people for some reason seem to want more and more of their leisure time spent in passivity being "stimulated" by bright colors and nice sounds and (more concretely)

as the amount of information available to oneself and one's competitors grows exponentially (witness, for example, the growth of traffic on the internet), automated personal assistants are coming to the fore. Soon, perhaps, we may not need to talk to each other at all but me, I'm going to the bar. Interest is growing in "agents" which can be set to perform particular tasks, for example finding a movie, searching one's e-mail for relevant items (an unenviable task, to be sure, but someone's gotta do it). The most interesting problems in agent technology relate to choice of actions; one has to be sure that one agent's action does not interfere with another's. We are using agent technology in the SONAS system – see Kelleher et al, 2000.

AI has been held partly to blame in this chapter for some of the functionalist excesses of CS. It should also be said that recently some AI researchers have produced brilliant implementations of situated, embodied themes. We already noted some such in active NLP and vision and the work of Rod Brooks. The culture of AI includes an implementation-orientation, sense of fun and adventure, and self-confidence which is often not even wholly misplaced leading to the possibility of breakthrough. Virtual reality may progress to the point that Piaget's notion about a genetically-constrained set of possible worlds may be tested; some recent less celebrated work by Patti Maes and her colleagues at MIT may reach the market in some form, probably as a computer game, soon. One looks into body-length "mirror" screen and sees oneself accompanied by various creatures in an environment superimposed on the room one is in. One may interact with these creatures (for example, a small child) sometimes, as I witnessed, in rather morally abandoned and appalling ways by directing them to move, sit and…. I'd rather not say. The range of reference of this work is impressive, including using ethological methods to determine the salience of gesture (see chapter 6). For me, this kind of work is AI at its best. Unfortunately, MIT Media Lab may possibly abandon it

5.5 The current methodological debate

Before entering the arena of this worthwhile and fascinating debate, one more fruitless option must be eschewed i.e. cognitive psychology as AI. Human reasoning can only in a limit case emulate the kind of content independence which we've noted in AI production systems: the PDP situation, where the KL, algorithmic and implementational levels are all bundled together seems much more psychologically plausible. We have also looked in chapter 4 at the evidence against GOFAI as any type of realistic psychological model: PDP has better claims. Interestingly, the systems such as SOAR which claimed some such plausibility tend to be syntactic level, with all the technical shortcomings which we have seen that involves e.g. SOAR, such as PDP systems, has to be rewritten to a fair degree in order to acquire a new problem space.

The issues current in AI as a theory of mind include the following:

1. Where do we attribute the KL description? The current answer is: the observer's perception of the organism in interaction with the environment. We're going to find that this is precisely analogous to Bateson's view of Mind in Nature.
2. What is reflection? Currently, one hypothesis (from William J Clancey (1992)), whose views we'll refer to as the Willie Clancey School) is behaviourist: reflection is revision in behaviour.

3. We noted chunking in chapter 2 with respect to a morse code operator. Clancey reformulates it as regularization.
4. Conceptualization can be thought of as recomposing perceiving and behaving.
5. Understanding is viewed as a primary high-level function.

We are going to find ourselves agreeing with point 1 as a general view of mind and points 2–5 as a GOFAI view of the processes involved. However, the view of AI emerging from Brooks and his confrères may define each of those terms quite differently, with respect to an organism's/robot's ongoing interaction with the environment rather than its conceptualization of it.

The debate about situated cognition recently occupied an entire special issue of the journal *Cognitive Science* (Vol 17: Jan–Mar 1993). We can learn much from it in that, as a consequence of its main theme, it provided an excellent forum for discussion of (inter alia) the role of implementing computer systems in CS. I do not intend to try and resolve all the issues in this debate, but wish to flag certain points and consensuses relevant to us:

1. Symbolic cognition may also be situated, as we have continued to maintain.
2. The existence of specialized neural hardware for egocentric cognition is accepted even by the symbolic camp.
3. That camp feel that all that matters in CS is implemented computer systems.
4. Their notion of a symbol is that it is something which can designate or denote. The issues Searle raises (basically, designate or denote for whom?) are not confronted.
5. Anthropology's analysis of structures and relationships in the human world may reveal much of significance than the "symbolic" versus "situated" paradigms can reveal.
6. The framework here, which contrasts egocentric and intersubjective on one criterion, and posits the dimensions of symbolic, operational and ontological on another, holds up well in the light of this debate.
7. To a certain extent, we are revisiting the empiricism/rationalism debate of chapter 1.

5.5.1 Bateson's cybernetic approach to mind

Clancey pointedly invokes Gregory Bateson. It is apposite to look at his work. Bateson (1972, 1979) has concentrated a great deal of effort on precisely those aspects of the relationship between organism and environment which are most in question here. Moreover, he gives an account of mind which defines it in terms of general interaction between interrelated components. For Bateson, mind is "immanent" rather than "transcendent."

It must be remarked that Bateson is concerned first and foremost with restructuring those current concepts of mind and self he considers contributory to environmental destruction. "What must now be said is difficult.… I believe it to be important to the survival of the whole biosphere, which as you know is threatened" (Bateson, 1979). On a personal level, holding on too firmly to those concepts may lead to cataclysm in, for example, alcoholism. Indeed, Bateson goes on to identify these concepts with the same

Cartesian error to which Thinès (1977) objects: "the sobriety of the alcoholic is characterized by an unusually disastrous variant of the Cartesian dualism, the division between mind and matter, or, in this case, between conscious will or 'self' and the remainder of the personality" (Bateson, 1972).

He suggests that there are specific errors in the Western view of self. These errors manifest themselves on the individual level in personal dysfunctions such as alcoholism and on the level of social pathology in environmental destruction.

For Bateson, conscious purpose is a mixed blessing. It can act as a time-saving device, but tears one away from one's environment. The consequent rootlessness is at the base of certain of our current environmental and specifically medical ills. "Purposive consciousness is now empowered to upset the balances of the body of society, and of the biological world around us" (Bateson, 1972). Consciousness is treated as the time-saving device noted above. "Consciousness… is organized in terms of purpose. It is a short-cut device to enable you to get quickly at what you want: not to act with maximum wisdom in order to live…." Indeed, there are certain ends – particularly creative ones – for which the necessarily purposive structure of consciousness is inappropriate. 'We might say that in creative art man must experience himself – his total self – as a cybernetic model… in the making he must relax that arrogance in favor of a creative experience in which is conscious experience plays only a small part' (Bateson, 1972).

What alternative does Bateson offer to the apparently inappropriate Western-society rooted view of consciousness? Essentially: "The problem is systemic and the solution depends upon realizing this fact… man is only a part of larger systems and a part can never control the whole" (Bateson, 1972). The onset of this "systemic wisdom" (Bateson, 1972, 1979) must have associated with it an entirely new view of self.

Bateson contrasts the "systemic view" which takes interaction between man and environment as its focus for study with the traditional tenet of a transcendent self, "The total self-corrective unit which processes information… is a system whose boundaries do not at all coincide either with the boundaries of the body or what is called the self." This information-processing entity is immanent as opposed to transcendent, in character: "The system is not a transcendent entity as the self is supposed to be" (Bateson, 1972). Bateson considers the unsystemic viewpoint a characteristically Western error: "The average Occidental… even believes there is a delimited agent the 'self' which performed a delimited purposive action' (Bateson, 1972). Perhaps the word "delimited" is more appropriate than "transcendent."

What then is mind? In short: "A mind is an aggregate of interacting parts of components" (Bateson, 1979). Bateson hopes to come to an understanding of mind by making a list of criteria "… such that if any system satisfies the criteria listed, I should unhesitatingly say that the aggregate is a mind." Moreover: "I propose that the mind-body problem is soluble along lines here outlined' (Bateson, 1979).

A summary of Bateson's view is now called for as well as a process of relating them to certain themes of the present work. In essence, Bateson must be interpreted as proposing revision of certain current conceptions of the relationship between what we term "self" and what we term "world."

It should be obvious that Bateson's argument has marked similarities with Gibson's. What both Gibson and Bateson are saying amounts to a new account of the relationship between the internal and external worlds.

The view of mind emerging from AI (point 1 in this section) is essentially Bateson's view. Points 2–5 are essentially engineering prescription. AI has landed us unexpectedly right back were we started in the world of Gibson, Piaget and Merleau-Ponty. The champions of Bateson's position find arraigned against them a rearguard symbolic action; the framework of this book is proposed as a hospitable neutral forum.

5.6 Context, syntax and semantics

To introduce this section, let's do a re-take on several themes we introduced in chapter 3. Sub-language is a phenomenon in language where the context is sufficiently restricted to allow semantic relations to be given by syntactic formulae. At this level of restriction, the "syntactic-level" systems we discussed in 5.4 can elicit the relationships necessary. In short, if we look at the combination of (system + environment), the latter aspect is well-structured enough to afford the necessary relations after a syntactic analysis. The systems at the deeper level i.e. the semantic systems work in less well-structured environments and so must have "semantics" built into them.

Which leads us to the issue of what semantics in fact is. As a term, it is a late-nineteenth century innovation due to Bréal (Tamba, 1988). Its meaning is still unclear. Passmore (1966) cites several different meanings, including the study of how we can be confused by language! Moreover, the issue of what semanticians should actually be doing still awaits an answer. If they are merely characterizing the semantic content of various expressions, they lose connection with the world; if they insist with Jackendoff (1987, pp. 129–32) and against David Lewis, that semantics first requires characterization of a language of thought before proceeding, they run the risk of psychologism.

The viewpoint of this book is that many of these arguments can be resolved with a clearer model of context. Moreover, semantics, however understood, is not the sole vehicle for the communication of meaning. There is much truth in Edelman's and Polanyi's contention that meaning in an intersubjective domain requires consciousness and a self. The vehicle used can be syntax, pragmatics, semantics (either understood as "mentalese" or as model-theoretic if a neat model of the domain exists) or, as is the case most often, a combination of all of these. What precisely is used depends on the degree of restriction of context.

Context is normally used in AI systems with respect to constraints on the moment to moment relevance of knowledge. Let's note that the systems in 5.4 work because no pragmatics or other issues are relevant. All knowledge and behaviour are contextual: much work remains to be done in the proper characterization of context. The starting-point must be to shift the focus of analysis to (system+environment). Bickhard et al (1995) attempt to provide a formal grounding to a new approach to cognitive science from this starting-point. Theirs is one of the most significant books ever on the foundations of cognitive science, and their viewpoint's consistency is established by a scholarly review of the current alternatives. It awaits only implementation, as currently

the Nolanian system is undergoing in the Sonas system. Bickhard et al (op cit, p. ix) begin by arguing that all standard approaches to representation are "circular and incoherent." The fundamental problem both in AI and CS is that both disciplines are based on "Encoded symbols" (p. 11). We have already seen some consequent problems such as the frame problem; another line of counter-argument to encoded symbols is that their processing demands of the brain an ability to deal with them, in some "mentalese" dialect, off-line while new such symbols are being registered. Their "encodingism" is what makes them condemn the CYC system, and indeed Piaget. The alternative approach to AI, one approved both by Bickhard et al and this writer, is "using principled characteristics of interactions between agents and their environments to guide explanation and design" (Agre, 1996, p. 1). Agre's set of influences (op cit, p 20ff) is telling for the future of AI; it includes dynamic systems theory, active vision, Vygotskyan "activity theory," genetic epistemology, Buddhist and European phenomenology, and anthropology. In a theme which will re-emerge, crescendo, in our accompanying volume, Troxell and Cherian's characterisation of knowledge as "ability to engage in successful interaction with an environment" (Bickhard et al, 1995, p. 207) meets assent.

There is much that meets no such assent. Adrian Cussins is castigated for an undeveloped notion of implicitness; Stevan Harnad is anti-naturalistic and anti-scientific. Bill Clancey flirts with observer idealism, as do Maturana and Varela. Rodney Brooks and his followers such as Kuijpers and Tilden have "provided an interface between otherwise isolated modules and conference papers" (op cit, p. 2) though the former should, in his critique, restrict his animus to symbolically encoded representation, as the word "representation" is to have a role in the interactivist paradigm. Likewise, language utterances are to be viewed as operators on social realities (p. 72). This notion of language is seen as being held in common with Lucy Suchman's ethnomethodology, along with an emphasis on a social conception of knowledge, the world as background to every cognitive act, and an emphasis on mutual intelligibility. Bickhard et al. bemoan the fact that only HCI seems to have picked up on her work.

We will discuss ethnoscience in more detail in the next chapter; a great deal of current research by such as the Kellers and Edwin Hutchins places knowledge sources, in Gibsonian fashion, in the environment. The role of cognitive artefacts in shaping thought patterns indeed needs new emphasis. Such artefacts are produced in some way (which receives a neo-Hegelian treatment in the accompanying volume) by the society as a whole which leaves less work for the individual mind to do. Simulating this is indeed going to require as radical a re-think as Bickhard et al propose.

5.7 Mind in AI

Little remains to be added to the discussion in 5.5, but let us first of all review the path taken in this chapter. We first of all stressed the importance of AI for CS. This led us to discuss what exactly AI is, and to give a more veridical account of its history than normally appears. Science proceeds by paradigm shifts, and the most important audience for ideas is the next generation of talented researchers. For a variety of

reasons, AI failed to grab these for some time between the late 1960s and mid-1970s. AI is important for CS, but its influence has sometimes been subtly malign. We discussed the extent to which an over-emphasis on mental operations as computational to the exclusion of everything else has damaged CS. This led us to a wide-ranging discussion on the nature of CS.

We then discussed skeptics and their techniques. Wittgenstein and Husserl were assigned Knowledge Representation: in chapter 2, we had allotted logic to Piaget. KR problems were pointed out by Winograd, and in our discussion of the frame problem as well as the methodological issues in PDP in chapter 4. The notion of computation itself was assigned to Turing, Gödel and Penrose, all of whom emphasize the fact that there exists a set of problems for which it cannot be proven that they have a solution in finite time. Chomsky introduced the idea of parsing in chapter 3; here, his work was put into a broader context. The recognition of languages by an automaton was seen as equivalent to assessing whether problems had solutions in finite time. We briefly mentioned Marr, a syntactician of vision, and had some fun with Myles. The probabilistic approaches increasingly being used in NLP were introduced in the words of the venerable Bayes himself.

A theme that continues to present itself in this book is the relationship between syntactic and semantic: we use this distinction, coupled with sub-symbolic, to describe the achievements of AI. The discussion of Bateson, at least some of whose work is relevant, explored the consequences of positing the knowledge-level description, or the attribution of mind, to the interaction of system plus environment. The framework of this book is enriched by this consideration, and holds up well in the current symbolic/situated debate (as it's often unfortunately put).

5.8 Texts on AI

A plethora of texts exist. You could do much worse than use a combination of Tanimoto (1990) with its introduction to Lisp and working programs, and Partridge (1991) with its comprehensive account of the field.

6. Ethology and Ethnoscience

6.1 Ethology

6.1.1 Can Ethology explain everything?

Animals often seem very stupid when put in continued experimental set-ups. Pigeons pick at lights in Skinner boxes when the reinforcement arrives according to a time, rather than a pecking schedule: rats continue to try and travel by a previously-chosen path which is now electrically live. An adage which is used for these situations is that there are no stupid animals, but plenty of badly-designed experiments. It seems appropriate to try and study the behaviour of animals in their natural environment (ethology).

When we do so, we find many astonishing manifestations of Mind in nature. In fact, here more than anywhere else we see that Mind is best viewed as the adaptation of an organism to an environment over time, or better still of a species. This holds true regardless of whatever theory of evolution we choose, a choice which merits some comment.

First of all, when speaking of ethology, we are normally implicitly speaking of knowledge which is relatively directly genetically encoded. High school science worldwide describes how genetic information is encoded in Deoxyribonucleic acid (DNA) and that a chain of chemical events leads through RNA and amino acid expression of this information until we end with specific instructions for protein formation. In particular, DNA consists of a long chain of four molecular compounds. Sequences of three of these "bases" are read at a time by a cell, at a speed and time also specified on the DNA strand. Each base instructs the cell on which amino acid to include in a protein, the structure of which determines also its (the protein's) function. However, several issues must already be raised. Does one's individual experience have any influence on the structure of one's DNA? (Do the sons of toil really have horny hands?) If we accept so, we find the epithet "Lamarckian" being hurled at us: otherwise, we are politically correct neo-Darwinians. Secondly, how much of human behaviour can be explained in terms of the unfolding of one's genetic inheritance (the genome?). Sociobiologists believe a great deal of it is.

Let's consider the first question now. Neo-Darwinism states that there are only two ways by which a mutation can occur. One may be through an event such as radiation exposure effecting a change on the DNA. This is obviously inheritable and, if the offspring reproduces, it will be passed on. However, only a tiny fraction of these mutations are adaptive. An alternative route is a hitch in the transmission chain from nucleic through amino acids. Again, this is more than likely to be maladaptive and is probably not inheritable.

Lamarckianism, by contrast, insists that one's DNA reflects experiential data as well as experiences one undergoes passively, such as Chernobyl or Sellafield. By historical irony, Darwin himself held a Lamarckian view of inheritance. This particular controversy has raged over the last century, causing the suicide of at least one brilliant evolutionary biologist (Paul Kammerer's story can be read in Koestler's *The Case of the Midwife Toad*) and the evidence is ambiguous, although analysis of bacterial immunology has been interpreted to indicate Lamarckian inheritance does occur, leading neo-Darwinians such as Dawkins to shout "fraud."

Let's start to put this debate in the wider context it deserves. We noted in chapter 3 that language, considered as a static monolith, afforded only a puzzlingly layered system with paradoxical types of interactions between layers. Considered in use, the paradoxes disappeared. Similarly when considered as theories of the progressive adaptation of a species to an environment, i.e. Mind in nature, there is no significant difference between neo-Darwinism and Lamarckianism. This progressive adaptation often involves the appropriation, over time, of a response to the environment which was originally purely experiential. An example is the ostrich's developing calluses on its behind, which is too specific a response (to pain!) to admit of a straight neo-Darwinian explanation. However, if viewed in the terms of the species long-term engagement with its environment (what Waddington terms the epigenetic landscape), it is perfectly feasible that this response can be genetically assimilated.

Consequently, we need to look at the nexus of species and environment together over time in order to understand anything essential about evolution. A byproduct has been a resolution of the central abiding controversy in evolutionary biology. With that in mind, let's now examine that secular religion usually called sociobiology.

Like most secular religions, there is a creation myth. Self-replicating molecules emerge from the primeval soup at a time of darkness over the earth. These molecules attract the detritus of the depths and manage to find ways to breathe form into this detritus. And then there was life, because it helps ensure the future happy replication of these molecules. Not only that the replicators instruct the detritus to form legs, fins, eyes, fur and brains, depending on what the environment requires, until we end up with humans in a world curiously resembling Planet Earth 2000 AD. And yes, said the high priests of Sociobiology, "Ye are that detritus. Only we are in contact with the Replicators." One now has precisely that sense of estrangement from one's own essential essence that the more nasty forms of religion can feed on, be they Freudianism or rampant Fundamentalism of any sort.

It is interesting that the Pontifex Maximus of this particular superstition, Richard Dawkins, admits that the notion of these Replicators consciously intending purposes, or using anything, is at best metaphorical (and at worst, perhaps, destructive nonsense). However, what we may term the "strong" sociobiology argument, taken to extremes as it often is, suggests that all the facts of human culture are gene-expressions. Even if, as is sometimes granted, the quirks characteristic of any given culture are not genetically pre-determined, the existence of a culture is.

We're again speaking eschatology (the religious sense of coming to an end), rather than science. Not one detailed aspect of higher-level cognition has had a specific

neurophysiological, let alone a genetic, correlate identified. Were the claims of sociobiology valid, ethology would be the basis for all Cognitive Science. At present, these claims have about as much scientific evidence going for them as Islam. Let's press ahead in learning what *has* actually been established in ethology.

6.1.2 Ethology and learning mechanisms

Ethology can tell us about certain types of egocentric knowledge. Much like myth as we discussed it in chapters 1 and 3, ethological knowledge tends to be unconscious and has a pervasive structuring effects on perception and action. It is not so much a building block as an architect's sketch for an entire part of the building.

The vocabulary of ethology must first be mastered before we pay attention to its specific findings. One issue that has already arisen with respect to child development is whether a species is precocial (i.e. develops early) or altricial (late-developing, with the attendant consequences for flexibility of later learning mechanisms). We must also introduce the notion of "set" as the predisposing influence affecting the probability of an event. These events are normally types of behaviour in response to environmental stimuli. Phylogenetic sets are due to one's species, ontogenetic sets to one's particular nature. We can also distinguish experiential and individual sets. An archetype of phylogenetic set is the digger wasp's egg-laying pattern. She builds a nest and kills a caterpillar which will feed the newborn. The nest is then marked by a marker such as a pine cone.

Inherited learning patterns include items of various degrees of specificity. Kineses, which are stereotyped types of movement and reflexes, which also require certain stimuli, are very specific. Fixed action patterns, including e.g. smiling, are less so. It would obviously be a pointless exercise to try and base a worthwhile science of cognition on these impoverished foundations.

Let us note just one more critical concept. "Critical periods" refer to times during development when the learning of certain items is optimized for a species. If kittens don't early on get experience of vertical stripes, they remain blind to them. Close to birth, goslings can be imprinted on Konrad Lorenz as on their mother. A celebrated series of photographs shows the goslings dutifully following the famous ethologist. This type of knowledge, then, is hard-coded and may be hard-coded incorrectly. That fact certainly gives pause.

6.1.3 Mind in ethology

We've stressed that in biological systems, a fortiori evolution can sensibly be viewed only over time and as species adaptation. In this, we see *Nous* at its most evident. The spider constructs a web as though it knows the principles of tensile engineering: the honey bee's dance shows a superb sense of how symbols can represent reality. Moreover, above all, we see the occasional necessity of distinguishing Mind per se from conscious mental life.

6.2 Ethnoscience

Ethnoscience focuses on discovering how individuals in different cultures organize and use their cultures. In particular, it looks at how this knowledge manifests itself in language. AS such, it is related to the following disciplines:

1. Ethnography, which focuses on the modes of life of various groups.
2. Anthropology, which exposes the basis structural relationship underlying human social life and organization.
3. Latterly, a lot of experimental research on cross-cultural cognition has been done, which attempts to perform a comparative analysis in particular of the act of categorization.

6.2.1 Ethnography and anthropology

These disciplines were profoundly influenced by the work of Lévi-Strauss, who was an admirer of Merleau-Ponty. His intellectual debt was more to structuralism, than phenomenology: the former discipline attempts to elicit the invariant laws of relation of the phenomena under examination. In linguistics, for example, the use of a word would be viewed only in the context of the other words with which it formed a structural whole. We are back to Wittgenstein: we know what "dog" means (almost), but for "the" we must look at how this word is used in the whole language itself.

Indeed, anthropology is seen as profoundly connected with linguistics, and Lévi-Strauss would have been very sympathetic to Chomsky's search for a Universal Grammar. Linguistics is seen in this light as a social science: sociology itself is viewed as an anthropology of a single society, a plotting out of the structural relationships underpinning human life and organization for a single case.

It has to be said that neither subject can truly be said to belong to CS, which works best as a forum for studying the activity of an individual mind insofar as that activity can be informationally characterized. In the broader context of its role in a federation of sciences of mind, CS often finds itself being greatly informed by the conclusions of anthropologists and sociologists, but their activity in attempting to intuit structural relationships is not essentially a CS one.

Anthropological fieldwork has varied greatly in quality. In Ireland, we are more used than most to intrusive researchers asking terribly stupid questions before writing up the extraordinary and deliberate fabrications they receive as PhD theses. The Samoan islanders found themselves in the thirties portrayed as 1960s Haight-Ashbury flower children in Margaret Mead's *Coming of Age in Samoa*. To understand a culture seems to involve an immersion therein, a compassionate desire to experience its depths as well as its heights, and much creative insight.

Sermon over, let's return to Lévi-Strauss. His conclusions are interesting:

1. Consciousness arises neither from culture, nor language.
2. Language and Thought are separate: the former is not necessary for the latter (this viewpoint is one that we expounded in chapter 3).
3. Myths are all-pervasive in mental life, for which they supply the formal structures or patterns, even if their influence remains unconscious.

For Lévi-Strauss, one of the crucial points about myths is that they revealed mind in its pure form, free from objects. He undertook an atomistic analysis of myths, noting elements such as the undervaluing of blood ties exemplified by the content of the Oedipus myth and the foot deformity (Oedipus means "swollen foot"). These concrete details, he argued, were used to approach more abstract struggles such as that between nature and culture. They need have no precise content a priori in themselves: the architect's plan is not the brickwork (the map is not the territory). Again, as was the case in ethology, we find ourselves meeting powerful, structural forces just beyond the point at which we can articulate our experience.

Given ethnoscience's attempt to analyze the thought-structures of ours and other cultures, we could perhaps usefully set it the task of comparing the analytic philosophy tribe with the Continentals. With this ice broken, the possibilities become endless. Eliminative materialists as cargo cultists… the millennial teachings of Sociobiology. In fact, the social sciences in general can yield rich pickings for researchers hungry to find ethnic groups working in closed cognitive systems safely remote from reality.

6.2.2 Cross-cultural cognition

Much research effort has gone into explicating the systems of categorizations different cultures use to deal with their environments. It is found, for example, that a Wall Street trader evaluating blue-chips might use precisely the same formal structure as a South Sea Islander choosing a tree from which to build a boat. To spoil the story, the conclusion fits in very much with the Principle of Rationality: the cognitive system will work opportunistically to maximize its adaptation, using whatever formal structure fits. Indeed, the entire cultural system involving religion, tribal bonding, a language in which women, fire and dangerous things might have the same symbol (in Lakoff's famous example), can be seen as a program which optimally chunks experience.

A fundamental finding has been that certain (base) levels of conceptual analysis have privileged possibilities. The class "tool" admits of the base level of hammer, saw and other levels such as mallet, hacksaw. Base level categories seem to have a psychological priority. Moreover, conceptual abstraction seems to be universally done by prototypes (e.g. one visualizes an archetypal hammer), in contrast to which examples are seen as having a stronger or weaker family resemblance. (Two members A and B of a family may have the same color eyes, but a different nose; vice versa for members B and C; yet all are identifiable as siblings).

In conjunction with this research, Eleanor Rosch (1974) found a cross-cultural tendency for categorization of colors with respect to three foci on the spectrum, roughly analogous to the primary colors. All this evidence together suggests that nominalism (see chapter 1) is inferior to conceptualism in some ways: concepts seem to emerge naturally from experience, rather than impositions of one's vocabulary.

In fact, yet another alternative proposed foundation for CS focuses on cross-cultural cognition. The central notion is that cognition is strongly dependent on the nature of the brain/body unity and that many aspects of the conceptualization which structures our cognition derive from the kind of universal experience captured in image schemas

and their ilk. Lakoff, we note below, rightly suggests that we extend the structures of physical experience by metaphor to other domains. This is very much compatible with the Nolanian framework but we shall note some caveats.

In this context, Terry Regier's work has received a loud fanfare. Its range of reference is impressively wide: cognitive linguistics aficionados have received him with open arms, and it includes also linking of natural language and vision, cross-cultural studies of both perception and cognition and some ingenious ad hoc PDP solutions. The input his system receives is videos of simple block and blob shapes implementing actions that will be described by spatial prepositions from various languages. English is actually very weak in such constructs; for example, the notion "up from underneath" is handled by a single term in both Gaelic (aníos) and Russian (izpod). Regier himself makes far fewer claims for his system than does George Lakoff, who sees predictions from his cognitive models notions of Language fulfilled in detail. In fact, Lakoff is inclined to use Regier's work as proof positive that, yes, spatial language does in fact involve projection of the body and kinesthesis onto external space. For example, "on" =force + support. Lakoff continues to emphasize the point above that whole cognitive domains derive their structure from the metaphorical extension of others. Love is a journey, and a relationship is a vehicle which may be upended, stalled or run off the road. One problem with this notion is that counterexamples tend simply to be ignored; it is difficult to see what Lakoff would accept as a counterexample. Love is a rose with thorns…? A many-splendored thing?

Another really consequential issue emerges in this context. The emphasis on the individual mind in CS is counterbalanced, as we saw in chapter 1, by work such as Hutchins' which looks at the cognitive artifacts in societies and (as we saw, fallaciously) proposed that internalization of one's dealings with these explained cognition. I feel the real question here is: what is an object, that we should know it? For you and I to have dialogue, we must refer to a set of intersubjectively validated tokens, some of can be identified with the "container" schema and its like. (It is argued in chapter 8 that the experience of oneself as object is similarly compelling in the manner we sought for the foundations of Psychology in chapter 2). These schemas can be extended metaphorically, as noted above; it is my belief, however, that the intersubjective domain holds more than this as the operational knowledge interacts with the symbol systems.

Let's again look at the mathematical diversion which originally was Riemann geometry. Einstein found that, used in a four-dimensional space, it afforded precisely the kinds of effects (e.g. the curving of space-time by gravity) which he needed for general relativity. In other words, the formal game turned out to be the best model of the universe. The relationship of mind and world here is of quite a different nature to the necessarily psychologistic ethos of cross-cultural cognition. Something mysterious is afoot, some manner in which we indeed are microcosms.

It may be appropriate also to remind ourselves of culture-specificity. At this stage, let's also remind ourselves of pygmies' inability to interpret photos. Their native "language of vision" doesn't include this, nor the ability to determine that a buffalo one mile away looks small, but is really rather large. They are, in turn, unquestionably

attuned to their environment in ways that we in the West cannot understand, and from which we have much to learn.

6.3 Mind in Ethology and Ethnoscience

In both these cases, mind is manifest and best appreciated *in situ* and as the process of adaptation. Moreover, the animal's being wrenched from its environment into the laboratory, or the non-Western human being asked questions from a western academic's viewpoint tears the fabric of the organism/environment continuum to the point where we completely lose what we set out to observe in the first place. We must also, from this chapter, yet again note the informing role of myth, archetypes and ethological learning mechanisms. The role of anthropology concerned us briefly, as did the nature of the intersubjective domain, leading to surprising conclusions about aspects of the mind/world relationship.

6.4 Further Reading

Flanagan (1991) provides a worthwhile account of sociobiology in a CS setting. Gardner (1985) provides a good account of ethnoscience.

Part II – A New Foundation for Cognitive Science

Introduction

The general outlines for the new foundation for Cognitive Science will be reviewed at this stage. These following themes, the central principles of the new foundation, are consistent with and afford a perspective which allows insight into the main findings from the principal constituent disciplines of Cognitive Science.

1. Mind is best viewed in terms of the co-adaptation over time of organism and environment.
2. Human Cognition admits of distinct egocentric and intersubjective modes. The latter mode, in turn, admits of a contrastive autistic realm.
3. Symbols can usefully be viewed with respect to the ontological, symbolic and operational knowledge dimensions.
4. It is useful to distinguish cognition from perception in the following terms (rather then those of a symbol/non-symbol dichotomy): Cognition refers to any mental process by the organism which attempts to transcend its environment; Perception, by contrast, is a process which involves the maintenance of a stable relationship with the environment.
5. Cognition cannot be fully discussed except with respect to its development as progressive adaptation to and mastery of an environment.
6. The Nolanian framework has been elaborating itself as we progress through the constituent disciplines; all will be revealed in chapter 9.

These two chapters (7 and 8) broaden the context of the discussion. We need, first of all, to look at human symbolic behaviour in as many of its manifestations as possible. Secondly, we need carefully to scrutinise the topic which many people identify as mind i.e. conscious experience. So much has been written about this recently that, for once we must explicitly confront and criticize other viewpoints. More than any other, this topic will define what the sciences of mind, including Cognitive Science, have to contribute to our view of ourselves.

The forthcoming account deliberately refers to real human experience in the real world a great deal. It must do so to have ecological validity. For its methodological justification, we journeyed down many nooks and crannies in chapter 1. Its justification in terms of the other disciplines was spelled out at length in the appropriate chapters.

Cognitive Science should tell us something new about our experience other than the pious and probably misguided hope that it will be eventually treated with the same concepts as the hard sciences. It should say that something with passion rather than complacency accompanying the "certainty" that no life-enhancing notions will ever emerge from the grinding of its dark mills. In fact, eliminative materialists are probably correct in castigating a great deal of our folk psychology concepts: however, our notions of "self," "intent," "feeling," and "belief" might just as easily be transcended through their correct analysis as eliminated.

7. Symbol Systems

7.1 Characteristics of symbol systems

This chapter explores the nature and use of symbol-systems such as those of language, music and mathematics. Many of these findings are also appropriate for vision: visual perception involves the use of symbols often unconsciously picked up from one's culture or, as in the case of Western society, produced by the conscious effort after realism in painting and photography. Gombrich's (1959) *Art and Illusion* is a superb history of pictorial representation which views the effort after realism in the art before photography as a scientific enterprise, with one generations hypotheses being refined and surpassed by the next. Moreover, just as we found in chapter 3 that a generative grammar was a theory of the perception as it is of the production of language, so do we extend that bidirectionality to other symbol-systems such as music and mathematics. Finally, we find that the following properties hold for those systems as they did for language:

1. A hierarchical organization. In language, we found that a top-level description such as Sentence fragmented itself into further description such as NP and VP with the possibility also that (there would be a recursive addition of a sentence within a sentence)). Similarly, in music the top-level description of leitmotif governs the unfolding of a whole section of a sonata: a tennis-player's game-plan (e.g. I bring her to the net on a backhand approach, and lob her) will set down the rules of the grammar to which every shot must cohere: a cubist painter's top-level theme regulates the structure of every fragment of a painting such as Picasso's *Man with a clarinet*.
2. The symbol systems must be of a certain complexity, neither too great nor too small. We've noted that natural language falls between Chomsky type 1 and type 2. Remarkably, this stricture holds also for music. For example, attempts to describe Irish folk music with the "finite state" Type 3 grammar of pentatonic theory have always come to grief. Conversely, whenever art music has exceeded a certain level of formal complexity, as in the cases of Schoenberg and Palestrina, a reaction has set in to simplify matters. For example, Monteverdi reinstated the use of monody (single note melodies) as a riposte to Palestrina's polyphonic excesses.
3. A recursive structure. I promise that (I'm not going to give this natural language example again). This structure holds true for music to much the same extent: a phrase in music can be of the classic NL recursive form:

   $$S \rightarrow \bar{\bar{x}}\ \bar{\bar{S}}$$

   i.e. the "tail" of a musical phrase can become the theme of a quite separate development. Whatever about the precise depth of recursion that humans can

handle – and it undoubtedly can be increased greatly with expertise in the domain (shades of PDP!) – its existence is not in doubt, or otherwise finite state grammars would be sufficient.

4. Idiosyncratic combination with operational knowledge. We've noted that this is precisely the difficulty with NLP. Moreover, this combination is part of the definition of context.
5. Metaphor. The moon may be a ghostly galleon, and likewise Piet Mondrian will draw a busy jumble of little boxes and call it *Broadway Honky-Tonk* (Gombrich, 1959). In both cases, we need some initiation into the forms available to Coleridge and Mondrian respectively in order fully to appreciate the metaphor. Metaphor in art, like play, is above all the exploitation of the emotive qualities of acontextual material. We saw in chapter 6 how it can be used as a general cognitive mechanism.
6. Emotional impact. One of the most appalling errors in Cognitive Science has been the notion that one can say anything coherent about cognition and its development without taking into account emotional and motivational factors. Moreover, as we saw in chapter 2, "emotion" can have a "cognitive" content: the scare-quotes are there to indicate how artificial this distinction often is. For a great artist, moreover, so certain is he of emotional impact that emotions are a vehicle rather than a destination. The final experience is as certain to be achieved by a careful experiencing of the artwork as the conclusion of the proof of a theorem.
7. The Possibility of self-reference. Gödel's work, which we outlined in chapter 5, essentially establishes the following: any formal system of power greater than or equal to standard arithmetic will contain within itself propositions which can neither be proven nor disproved within the system. One such proposition is "This system is consistent." Another such is "This system is inconsistent" (We shall call these respectively G (F) and (not G (F)) in chapter 8). This state of affairs is best described in philosophy by the paradox of Epimenides the Cretan, who declares that "All Cretans are Liars." If he's right, he's wrong (and vice versa).

   Self-reference is a momentary realization as we evaluate systems, not a continual state of any type. We noted in our discussion of post-modernism in chapter 5 that reading such a novel requires one at times, with a jolt, to undergo a transition from one narrator's structure to another. In essence, the identifications and concerns one had at level 1 must be withdrawn from and seen as objects at level 2 of the narrative. One must in some sense become an object to oneself. That process Penrose identifies as consciousness in its pristine non-algorithmic form: it certainly is one type of cognitive transition which is crucial to consciousness. Once fooled that way once, we will never be fooled again, unless for some reason (e.g. TV soap opera watchers) we wish to be.

   René Magritte famously produced a set of paintings which referred to themselves at level 2 to isolate the expectancies lined up at level one: a picture of a dog might be captioned "*Ce n'est pas un chien*" (Hofstadter, 1979 has hundreds of such examples drawn from mathematics logic, music and art). Likewise, Bach's "eternally rising fugue" (a kind of musical barber pole) can be seen at level 1, from the inside, as the exposition of a theme within each separate key with frequent

shocks as one enters a new key and from level 2 as a prescription for modulation between keys. Once seen from level 2, like all the other examples in this section, we can enter level 1 only through a deliberate act of self-deception. (Hofstadter, 1979) is full of such examples.

8. A stack. In order to implement recursion (as in iii), we need a stack. The weakest grammar which can support recursion necessarily uses the computational device of the stack Burnod (1990) shows how stacks might be neurophysiologically implemented The fact that recursion is such a dominant structure both in symbolic behaviour and action (e.g. in order to do X, I might first have to do Y, which involves doing Z) not only testifies to the paramount importance of the stack structure, but also indicates that all these formal systems may be implemented at a neural level by a general-purpose symbol system. Thus, we are faced with two conclusions:
   a. The semantics of all symbol systems are based in a common bank of conceptual structure, including operational knowledge.
   b. Even at the syntactic level, these systems admit of a common neural architecture.
9. Ambiguity. Language we have explored: visual ambiguity is best illustrated with illusions such as the Müller-Lyer: musical ambiguity is a more subtle matter. Listen to the opening bar of *Autumn Leaves* (Figure 7.1). Is this major or minor? Obviously minor, you who have listened to it before will say. Yet that is an a posteriori decision: there is absolutely nothing in that bar to give away its harmonic nature. As is the case with language, disambiguation requires a context which is supplied only over time. Indeed, skilled musicians would regard the question as trite; to establish the key, one listens to a goodly section of the piece.

10 Systematicity. The effort to use this particular buzzword as a rod with which to beat PDP is a topic we've discussed in chapter 4. The conclusion has to be that just as the nature of "variables" is a deeper and darker mystery than we might have thought, so also is human reasoning often quite content-dependent precisely in the manner of PDP systems. Indeed, it seems necessary even in (Pythagorean see chapter 1) GOFAI systems to introduce content-dependencies at the semantic level, as distinct from pure syntactic regularity, in order to increase the power of these systems.

   Finally, we saw that neural nets can be trained to perform the type of tasks which the wielders of systematicity like to focus on.

11. A multi-layered organization, with hypotheses being lined up in parallel. We have emphasized in chapter 3 that language can be understood only in this light and that nature has gifted us the kind of blackboard architecture we need to implement it.

    The PDP model of reading text, where we've seen that words, collocations and phrases can affect and be affected by phonemes as well as each other, can be extended also to musical score reading. Familiar chords may be viewed as words in this light, familiar chord sequences as sentences. For example, we expect the notes GBD to occur in various permutations frequently for a piece in G major, since they form the tonic thereof: likewise, (to simplify) we expect the note sequence in the same key of DACF$^{\#}$ eventually to end with G natural as the piece resolves.

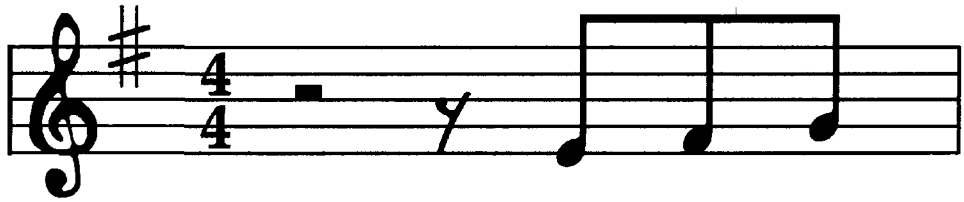


Figure 7.1

12. Comprehensibility only with respect to a task. We observed that language as a system seems an incomprehensible set of conundrums until we observe it in practice (also Ó Nualláin 1993). The same holds for music: the latitude allowed for key changes and rare intervals is going to vary greatly as the piece changes in length from a symphonic movement (with its great latitude) to a pop song (extremely slight).
13. Various types of objectivity. In language, we noted a huge range of the symbol/world relationship from Wittgenstein's laborer's "Slab!" to extended discourse. Likewise, the visual arts might be directly representationalist like Constable, or allusive like Mondrian. Mathematics extends its objectivity from counting "4 is the number of elements here" to Riemannian geometry, a theoretical formalist game which we saw turned out to be the best objective model of time-space. In Music, we might usefully contrast the Objectivity of the Storm section in Beethoven's pastorale with his evocation of eternity in the opening section of Opus 131.
14. Situatedness. This we treat in our 3-D notion of symbolic behaviour. One does not truly perform any authentic symbolic act except in a social and cultural context. As you speak, you are tacitly aware of the expectations of those to whom you are speaking: you are an object to them in the real sense. A pathological state of self-alienation can arise if you become also a stranger to yourself (see Psychogenic Fugue in chapter 2: the topic of self-alienation is handled brilliantly by the existentialist psychiatrist R D Laing in *The Divided Self*). Similarly, the meaning of a musical phrase is going to change greatly depending on whether the musician is playing a sonata, a concerto or a pop song (where a long phrase is normally acontextual, and may be there for humorous effect, e.g. the Opera section in *Bohemian Rhapsody*).
15. Closely related to this is the notion that symbolic behaviour of all sorts needs a *native language*. It is a commonplace that non-native speakers never fully master a spoken language. Of equal interest are the native languages of vision and music. We have noted several times that pygmies, lacking our Western exposure to sharp angles in the course of their early development, cannot interpret photographs as we do and that doubtless they are sensitive to much visual distinction that we miss. Our stock of visual distinctions we can regard as our language of vision (at the syntactic level): we are not stretching matters if we carry the analogy further to the point where we insist that all languages of vision fall within certain tightly

circumscribed limits of formal complexity. This is certainly the case for folk music: the native human language of music tends to be surprisingly complex. For example, the rhythmic patterns of Balkan music exceed Western art music in complexity. Let us therefore jettison any Western chauvinism, or – given the brilliance of much non-verbal symbolic behaviour – any intellectual chauvinism for verbal as distinct for other types of intelligence.

16. *Certain universals with respect to the learning of these systems.*
That this is the case for language we demonstrated in chapter 3. Autistic idiots savants in other modalities can perhaps best be viewed as the exceptions which prove the rule: in general, musical or visual development will follow certain definite patterns. For example, a logarithmic law seems to relate number of trials with the increase achieved in skill.

17. *Creativity*
It's appropriate here to make explicit a distinction which has so far in this chapter been implicit. Symbol systems as formally treated demonstrate syntactic regularity captured by grammars and feature properties such as 1, 2, 3, 4 (and so on) above. "Creativity" in this sense merely refers to the astounding facts that the number of possible English sentence within the compass of a native speaker exceeds the number of protons in the universe (or some such quantity). Symbol systems as used in cognition, normally in interaction with other cognitive abilities, feature properties such as 4, 5, and so on and it's these which bear a more interesting relation to creativity.

Computer creativity, including in music, has again been receiving a lot of attention. It is fair to say that a consensus is emerging that, since we can view the talented composer (or author, or scientist) strictly in terms of the (musical) schemas (Bartlett 1932) he has at his disposal, we can soon expect Mozart's 42nd, Beethoven's 10th (sometimes identified as Brahms' 1st) and so on. Much as I would enjoy these offerings, I doubt it very much. I believe there are several good reasons for why not.

One such is that creativity involves identifying problems as well as solving them. It can start just from that ill-defined feeling of dissatisfaction with established forms with which creative people terrorize the rest of us. Some evolutionary impulse drives them out to explore the space opened up by the symbol system. Interestingly, composers such as Beethoven saw themselves as discoverers in such a space, not inventors. Reason 1, then, is that problem-definition often emerges from visceral intuitions of mismatch which are totally unformalizable. In retrospect, we can of course formalize them; my hunch is that their true origin, in the genius' relationship to the world around them, is currently totally beyond us.

Secondly, creativity often involves "paradigm shifts." I don't wish to refer to anything as complex as the symphonic and sonata-form innovations of Beethoven here, or general relativity. Let's take *Autumn Leaves* as an example again: figure 7.1 is the first bar of a polite version of the tune. However, Miles Davis on *Somethin' else* introduces it with this bass-line (figure 7.2), written on the treble staff for the guitarists among you. It's written with two flats, and actually defines the old

Figure 7.2

Church Dorian mode (figure 7.3 is a clearer definition) so F major is the most appropriate scale. What has happened? Essentially, jazz has now left diatonic music behind; though Miles goes on to play the tune straight after the intro, a redefinition has been achieved.

Finally, in a way which cognitive linguists would approve, the moment of creation often seems inextricably tied in with aspects of our messy, imperfect, incarnated humanity. An example is Kékulé's discovery of the benzene ring. Stumped by the question of how 6 hydrogen and Carbon atoms could link together, he was startled by a dream of a snake swallowing its own tail. This archetypal symbol has often been interpreted (by von Neumann, inter alia) as depicting the original state of consciousness in the child (see chapter 8). Thus was the benzene ring discovered. One can hardly shy away from the conclusion that external reality seems to impress itself on us through visceral feelings, through dreams and in unpredictable ways inaccessible to algorithmic definition. And yes, this is relevant to CS.

7.2 Context and the layers of symbol systems

Consider again the conventional layered model of language in diagram 3.15.A fuller, more accurate description is supplied in diagram 3.16: whatever the layers, the point to be made here is precisely the same. These layers are an artificial abstraction and need to be considerably revised. With restriction of context, the previously apparently well-defined stratification becomes deformed to the point where a single deflection of the orientation of one part of a letter (e.g. K as R) can change the intent of a whole book.

The degree of restriction of context seems as counter-intuitive a priori as a focus for study of CS as Gibson's perceptual affordances. Yet we have seen in the case of language that previously intractable problems fall readily at its analysis. A similar situation exists for music, where meaning is even more difficult.

7.3 Mind and symbol systems

In this chapter, we've mainly been concerned with extending the analysis of language in use in chapter 3 to symbol systems in general. A general architecture for these systems distinct from the specifics of there use was proposed. We predicated a lists of attributes of them and yet again found the mind/world relationship crucial in understanding their use.

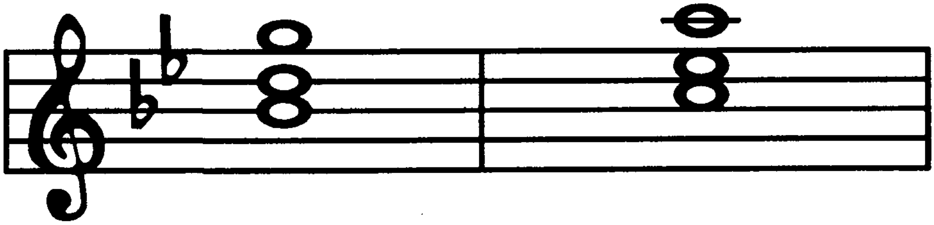


Figure 7.3

7.4 Further reading

Hofstadter's (1979) *Gödel, Escher, Bach* is a brilliant study of isomorphisms between music, logic and art. Gombrich (1959) is an analysis of the science of pictorial representation. Jackendoff (1987) is a scholarly analysis of parallels between music, language and vision. See McKevitt et al. (2000) for the details of a conference dedicated to the themes of this chapter.

8. Consciousness and Selfhood

Introduction

With the advent of the scientific (which, ignoring matters of etymology, I shall identify with "empirical" for the purposes of this account) study of Consciousness, we have reached a crisis in the sciences of the mind. It can justifiably be argued that this crisis, more than anything else, has caused the current turbulence in CS. In fact, it can be argued that consciousness study will determine one limit of the empirical in the sciences of mind. The stakes are high indeed. We should consequently approach the subject with a degree of fear and trembling. It is not enough simply to investigate psychological processes, of whatever degree of interest (commisurectomy, subliminal "perception" etc) and add the noun "Consciousness" to the title of what is essentially a paper about an information-processing (classical CS) phenomenon. One way out, of course, is to predicate a phenomenal aspect of information. The difficulty with this approach is that it requires that any information-processing device should by definition be considered conscious. We shall avoid any "magic bullet" solutions here; the path taken is to be quite different.

To complicate matters, all genuine spiritual traditions have a discipline involving the transformation of consciousness (as they conceive it) guided by an inner empiricism whose rules of inference and criteria of evidence may be quite different to what we call "science." They state their methodology in a quaint language whose lexicon includes virgin births, *samsara* and *karma*; the compilation of this into anything resembling normal Western discourse is complicated beyond belief (Needleman, 1982). Yet this source of evidence cannot be ruled out. The traditions don't claim to talk directly to you or me; we must in some way be ready. The critical transitions of consciousness are intersubjectively validated (Polanyi, 1958, argues that Western Science's criterion is precisely the same) despite their not being "objective" in the sense Western Science allows, to which they answer "so much the worse for Western Science." In short, this is empiricism of a different nature, and to spurn it is to throw away a huge part of humanity's search for self-understanding. As it stands, CS cannot take this inner empiricism on board; nor, in fairness, can they take cs. The study of consciousness in CS must inevitably be essentially a projection into phenomenological space of the methods of "objective" science. However – and here comes the big disclaimer – we will have to concede that consciousness is a much larger topic than the subset of its manifestations that we study in CS.

The notion of consciousness current in cs is something very close to Flanagan's (1992) idea (about qualia) that a conscious state has something it is like to be in it. We've had difficulty with yogis; we're now going to have them with bats. If they are conscious, at first glance it seems there must be "something it is like" to be one. At one extreme, we can't include Ramana Maharshi; at the other, we can't yet handle rodents.

All we can do is look at the functioning of conscious states and try to induce general rules and constraints. I wish to argue that the problem is with the notion of consciousness as in some sense experiential in the everyday sense of the word (mine and your experience, right now). Consciousness may be less than this for a bat, and more for the "self-realized." I for one am neither so can't say for sure; all of us are in the same position. Consciousness is *not* a single entity which has to be the same for humans as for bats. In fact, the conception of it I find most useful allows it to manifest itself in different ways in different beings. This gets rid of the classic Nagel objection (Flanagan, 1992) that because we don't know "what it is like to be" a bat, we can't say anything coherent about consciousness.

Consciousness seems, experientially, in some way less an object than a medium in which events happen. Those who work in the spiritual traditions see it as an occasional achievement, and the science of consciousness essentially as the increasing of the frequency and duration of these achievements. The self-realized, we are told, are continually conscious. In fact, we end up with that notion of consciousness at the end of this chapter. I believe that its main cognitive function lies in these occasional achievements, if we subtract the information-processing function of attention. Moreover, the work of Baars brings us to the verge of this notion.

But what of the bat? It is here that we must look for some phylogenetic evidence. Edelman (1992), as we shall see, distinguishes clearly the consciousness of lower animals, a precursor of attention, which consists essentially in the necessarily information-processing capacity to detect the salience of time-varying signals entering through different sensory modalities, from that of humans which consists also in the experience of a (mainly) linguistically-created self (Ó Nualláin, 1997, contains several treatments of this, including one by the present author). In other words, consciousness manifests itself in different ways. As we review the theorists in this chapter, we shall note bewilderingly diverse notions of it.

I believe that the insight that consciousness is not a monolith is the first step on constructing a valid theory thereof. Moreover, and here I am forced to be much more controversial, the essential grasp of what this thing consciousness *is* which manifests itself in such multifarious ways can only be arrived at experientially. There need not be anything it is like to be a bat, or even a dog; its manifestation at that level is other. (There is also a strong line of tradition which argues that consciousness is the basic stuff of the universe and matter but a "fold" in it. The universe is essentially a vehicle for "Geist" to become aware of itself, as evolution proceeds, through matter. Churchland (1988) reviews this and other such notions).

More theology coming, I'm afraid. Mystics identify two paths toward the Godhead (interestingly identified as pure consciousness in some Indian mystical traditions) called the *via* (way) *positiva* and *via negativa*. The former would emphasize that God is in the world and can be experienced by dwelling in positive qualities such as truth and beauty. The latter emphasizes that god must be a truth and beauty beyond anything in the world with the appropriate call to indwelling. Scientists who study consciousness fit into similar negative and positive camps: those such as Penrose who reserve it for cognition of a Platonic form; and those such as Hameroff (surprisingly, his current

colleague) who argue that any creature with a cytoskeleton can be conscious. I will seem like a *via negativa* theorist by the end of this chapter, but this derives from the paucity of words in English to describe inner states; both paths are valid. I need to stake out an area of experience in which we authentically reach out to the external world, as distinct from the jumble of dulled sensation, daydream, stupid mistakes and half-baked sexual fantasy which occupies us so much of the time and find myself compelled to use the word "consciousness" for this area. What we do the rest of the time, with respect to the cognitive achievements therein, will probably eventually prove largely simulable by computer.

How then should consciousness be scientifically studied? We are about to note theories of quantum physicists, neuroscientists, cognitive scientists, philosophers (with rare reference to therapists and mystics). The first point is they need each other very badly. As a cognitive scientist, it helps me greatly to know the avenues opened by any demonstrations of quantum coherence in the cytoskeleton; yet it worries me that the scientists involved are inspired by the analogy with the "constant sense of self" at a time when the fragmentary notion of self is being emphasized in many contemporary studies. The notion of self, we shall see, is complex indeed. In other words, they should become much more familiar with each others' work. That also holds for those who claim to speak about consciousness on behalf of the religious traditions. As we shall see, Baars' work is a psychologist's contribution; Jackendoff (1987) describes consciousness in CS terms as the projection of informationally-characterized distinctions. We should also focus on the flip side, i.e. Con-scio-usness, consciousness as integrative (*con* = with, *scio* = I know). An opportunity to unify the sciences of mind in some kind of loose federation on this topic may then be afforded.

We need first of all to discuss a spectrum of current views on consciousness and its connection with selfhood. Some, such as Johnson-Laird's "mental models" view, are found inadequate for formal reasons. The others are investigated in the context of the historically-conditioned nature of the related concept of selfhood. It is found that they involve prescriptions for the construal of selfhood which are invalid and perhaps destructive. We then move on to discuss a more adequate view which interrelates the trio of selfhood, consciousness and will. The theory and its minimal set of assumed constructs are first outlined. We then proceed to interrelate it to the considerations of the rest of this book. The conclusion is a new notion of what is the real nature of consensual experience.

8.1 Cognitive views

Dennett's (1992) book, *Consciousness Explained* is a good starting-point for this discussion. Apart from offering a readable review of the relevant findings on Consciousness, it received massive publicity including, in Britain, a profile of the author in the London *Independent on Sunday*. (It is argued below that the publicity is more consequential than may immediately seem the case.) Let us examine Dennett's explanation of Consciousness.

Two crucial computational concepts must again be introduced: that of process and parallelism. The activities of a computer can be described in terms of processes which

can requisition the use of processors for their duration. In the human case, these processes may parse a sentence, construct a 2.5 D representation of a scene, or whatever. It is generally recognized that the great majority of fast processes must be unconscious. Moreover, given the relatively slow rate of neural transmission, the basic architecture must be parallel.

Consequently, Dennett (1992, pp. 253–4) summarizes his viewpoint thus:

> "There is no single, definitive stream of Consciousness: instead, there are multiple channels in which specialist circuits try, in parallel pandemonium to do their various things, creating multiple drafts as they go… some get promoted to further functional roles by the activity of a Virtual Machine in the brain."

Dennett has several opposing positions in mind as his argument unfolds (p. 97ff). The most reviled of these is the notion of Consciousness as a Cartesian Theatre, where scenes change in the presence of an audience which Descartes assumed was a unified self.

However, it is appropriate to inquire whether Dennett's concept of a "Virtual Machine" has any more explanatory value than Descartes' "Soul" interacting through the pineal gland. A Virtual Machine (VM) can be something as mundane as the user-interface offered by an operating system (Lister et al, 1988). Dennett would have to be much clearer than he is about exactly what type of VM he's speaking fo his theory to have any real content. Perhaps the most damning comment is Edelman's statement that it doesn't address the issue. Or, to put it in other terms, it's not specific enough even to be wrong.

Dennett is even more scathing on Descartes' view of selfhood. Self, he argues, is essentially fragmented (p. 426) and at best a center of narrative gravity (p. 410ff). In fact, in the case of multiple personalities, several such centres can exist. The consequences for moral responsibility are not spelled out in this popular book (p. 430). We must also ask whether experiencing one's self as narrative gravity is not perhaps an artefact of being a college professor. In other activities such as dance and music, the contents of consciousness and self are non-verbal.

A great deal of the book concerns itself with phenomena such as visual illusions (e.g. back cover) thought experiments (e.g. p. 124), neurophysiological evidence (e.g. p. 144ff) (it goes without saying that Dennett, like the other theorists in this section, is a monist), psychotic events, etc. In using this range of evidence and in his conclusions (and as he himself acknowledges (p. 257)), Dennett owed much to Baars (1988). Let us now attend to Baar's viewpoint, the recent developments in which will be treated in the final section of this chapter.

It is obvious in any account of consciousness and selfhood that both phenomenological and scientific evidence are relevant. Baars (1988) catalogues the relevant *explicanda* for any such account, e.g. self_attributed versus self_alienated experiences, eidetic imagery. He claims the following should hold true for conscious experiences (pp. 362–3):

1. That conscious experience involves generally broadcast information. Thus, this information is available to all effectors and action schemata.
2. Conscious events are internally consistent. This distinguishes them from dreams, even when the content of dreams is generally broadcast.
3. Conscious events are informative i.e. they place a demand for adaptation on other parts of the system.
4. Conscious events require access by the self_system.
5. Conscious events may require perceptual/imaginal events of some duration.

Baar's method is above all contrastive (p. 26). Conscious events are, in turn, contrasted with similar events in sleep/coma, habituated events, unconscious problem-solving, involuntary action, direction of attention. Finally, the characteristics of self-attributed and self-alien experiences are contrasted.

Baar's schema is economical in the extreme. There are only three significant entities: a global workspace, specialized unconscious processes, and contexts (p. 359). We may define the myriad phenomena of conscious mental life in these terms. Self is identified with deeper levels within the context hierarchy (pp. 361–3). Goal contexts can explicate will as a phenomenon (p. 361).

We end with three conceptions of Self: "The enduring higher levels of the Dominant context hierarchy" (p. 327); "That system whose change or violation as spontaneously interpreted as a loss of the sense of self" (ibid); "Self is that which has access to Consciousness" (p. 337). The question arises as to whether these conceptions are formally identical. Baars does not answer it.

The range of evidence which Baars surveys is impressive. His attack on the Cartesian Theatre is less pointed than Dennett's and he finds room for some aspects of it in his overall theory (p. 28ff). He suggests certain consequences of his theory: for example, he proposes an exercise to assist social self-control (p. 364). We shall find much to use in Baar's findings: however, we shall also find much to disagree with in his basic schema.

8.1.2 Computational theories of Consciousness

8.1.2.1 Consciousness as an operating system

Perhaps, the best introduction to this area is the work of Johnson-Laird (1983, 1988). For him, the operating system metaphor is to be extended well beyond mere mention of processes: we are to view consciousness, voluntarism and selfhood in its terms.

According to Johnson_Laird (1988): "Simple consciousness – the bare awareness of events such as pain – may owe its origin to the emergence of a high_level monitor from the web of parallel processes. This 'operating system' at the top of the hierarchy sets goals for lower level processes and monitors their performance" (p. 356).

This is an extraordinary statement. Such operating systems have been used for years, both on parallel and serial computers, without any imminent danger of consciousness emerging, even in the most far_fetched speculations of their creators.

Lister et al (1988) provide a concise outline of the architecture of a typical operating system. At the top level, the high_level scheduler assigns relative priorities to the processes in the process queue. On receiving these assigned priorities, the dispatcher selects a process to be run. The operating system is allowed to generate "interrupts" independently of the central processing unit, and thus may commence, abandon and recommence a process as is appropriate. Finally, a great deal of thought goes into semaphore systems and algorithms (e.g. the banker's algorithm) which maximize processor usage by processes. When abandoning one process in favor of another, the operating system must store the "volatile environment" of the abandoned process, if it is to be completed later. None of these complex operations require consciousness.

Despite this shaky ground, Johnson_Laird (1988) takes his argument several stages further.

> "… The conscious mind is the result of a special mode of processing that creates the subjective experience of awareness. Once an operating system had evolved, it could take on such a function, and this mode of processing, I believe, is our capacity for self_awareness" (p. 360).

Whence this special mode of processing? We have seen that it is unnecessary for an operating system to be conscious. However, Johnson_Laird (1988) is willing to go even further still:

> "… One of the operating system's options is to use its model of itself in tackling a problem, and this option in turn must be in the model, too. The circle is not vicious, but leads to the special mode of processing that is crucial for self_reflection and self_awareness" (p. 361).

However, the circle is vicious. No information_processing system can embody within itself an up_to_date representation of itself, including that representation. We have seen that Johnson_Laird is incorrect in his notion of the "operating system" origin of consciousness: his notion of a "special mode of processing" is also fallacious.

Let *A1… An* represent the state of a system at time *T*, where *A1, A2…* An are the propositions representing the system. The system must also, according to Johnson_Laird, represent itself. Let us call this representation, for argument's sale, *An*+1. At time *T+t*, the proposition *Ao* is added to the system. There must be time lags (1) before the proposition Ao is added to the system to produce *Ao… An* and (2) in particular, before *An*+1 is altered to cater for the advent of *Ao*. Therefore, it will be some time after *T+t* that the representation will be updated. We refer to a Gödelian argument again below in the discussion of Penrose.

Indeed, Johnson_Laird seems to notice this anomaly, and later refers to "partial models." Yet the criticism advanced above still stands as a caveat. The more important point is that an operating system need not, by any means, be conscious.

So far, Johnson_Laird (1988) has outlined a mistaken theory of the origin of awareness, and a fallacious idea of the nature of self_awareness. Unlike many other

uses of the computational metaphor, he does not commit himself to determinism: "We are free, not because we are ignorant of the roots of many of our decisions, which we certainly are, but because our models of ourselves enable us to choose how to choose" (p. 365).

This is simply a statement of the inexhaustible nature of self, and has no explanatory value because of the flaws in the rest of Johnson_Laird's system. The major thrust of this system is a thorough_going computational metaphor for mind, and its ultimate significance may be sociological. Lasch (1985) like Cushman (1990) (see below), comments on the malleability of one's self_concept. Johnson_Laird (1988) may be the first person to see himself so completely as a complex version of Unix. The ethical implications need not be spelled out.

8.1.2.2 The Society of Mind

For Minsky (1987) "Consciousness does not concern the present, but the past: it has to do with how we think about the records of our previous thoughts" (p. 150). As for selfhood, "we construct the myth of ourselves" (section 4.2). We must think of mind in terms of a system of agents with no central locus beyond a center of narrative gravity.

However, it can be argued that Minsky's statement on Consciousness is quite simply wrong in that it cannot explain how Consciousness can constitute objectivity and relate to the external world (see section 8.3 below). On selfhood, he may be nearer the mark than Baars, but for the wrong reasons (see section 8.2).

8.1.2.3 Conscious inessentialism: Jackendoff's Intermediate Level Theory

Jackendoff (1987) continues to quote approvingly Lashley's dictum that mental events are unconscious: "Lashley's Observation points to the necessary unawareness of the nature of information processing, no matter whether in perception, action, thought, or learning" (p. 319).

Conscious experience, then, is non-causal. In particular, Jackendoff inveighs strongly against Johnson-Laird for suggesting that Consciousness has the higher level contents he claims (pp. 285–7).

For Jackendoff, Consciousness contents are intermediate-level entities such as surface musical structure and phonological form (p. 289). Selfhood may exist in some sense, but if so it is grossly under-represented in Consciousness (pp. 299–300). Voluntarism may be discarded as an illusion if Consciousness events are in fact non-essential.

There is no questioning the excellence of Jackendoff's analysis of language and musical cognition. However, his enlistment of Lashley whose work was done long before a lot of essential neurophysiological techniques were available, may be a tactical error. Perhaps the best way to note the dangers of quoting Lashley in support of a monist, inessentialist position is by two quotes from Penfield: "Memory… is not in the cortex" (Wolf, 1984, p. 175); "In a sense, it is the mind… with its mechanisms which programs the brain" (Penfield, 1969, p. 904).

These quotes from another distinguished neuroscientist could be interpreted to support dualism: it is better, perhaps, to bracket both these and Lashley's statements

pending appropriate deconstruction. It would be interesting to know what Lashley would have to say about findings such as those of Libet (1979). Certainly, it is not good policy, as noted above, to rest one's case in these matters on the authority of any single thinker, however eminent. Jackendoff gives no justification for his inessentialist position beyond Lashley's dictum. Were he to found his case on a variety of phenomenological, psychological and neurophysiological data, it would be a great deal stronger.

The inessentialist position, even in its mildest formulation, is counterintuitive to the point of absurdity. It requires much more evidence than that supplied by Jackendoff. However, his contentions about the normal content of Consciousness can be accepted. More recently, he has been willing to allow consciousness some degree of causal power in that attention, the bright spot at its center, increases information-processing space.

8.1.2.4 Neural Darwinism

Neural Darwinism as neuroscience we looked in section 4.5. It is discussed as a theory of consciousness by Flanagan (1991, 1992), which we examine later. The brain is essentially a Darwin machine with the great majority of processes occurring unconsciously and all processes competing for resources. Evolution may have favored systems which allowed a subset of conscious processes along with these (p. 320ff).

Edelman's own theory is adequate as far as it goes. He argues that consciousness in its pristine form is 300 million years old: thus, one can predicate it of snakes. He identifies it as "… the ability to determine by internal criteria the salience of patterns among multiple parallel signals arising in complex environments" (1992, p. 133). This form of consciousness he describes with a striking metaphor: it is a beam of light illuminating a section of a dark room. However, higher-level consciousness in interlinked with selfhood, i.e. it "adds socially constructed selfhood" (ibid). Edelman's neurobiological argument is as usual superb; the latter part of this chapter works out the cognitive consequences, on which Edelman is not so strong.

8.1.3 A Mathematical view of Consciousness

Penrose's (1989) work is, as we've seen, an attack on his perception of the hard AI position. En route, he makes several far-reaching claims which we shall review later.

For the moment, let's consider his variations on Gödel. We can lexicographically or otherwise, order the set of propositions $Pn\ (x)$ in any particular system. Let the nth such proposition applied to W be $Pn\ (W)$. Let $P_k\ (k)$ be the Gödelian sentence (G (F)) for this system F.

Penrose argues that we can "see" that $P_k\ (K)$ is true although formally/algorithmically, the evidence is otherwise (p. 140ff).

Sloman (1992) argues against our seeing this, both on mathematical and intuitive grounds. He claims the math is incorrect, and the substitution (often of large) numbers in this way is counter-intuitive. Penrose would certainly argue against the latter point: in the former, the evidence is inconclusive. Sloman argues that there are models of F for which not (G (F)) is true; these models define non-standard arithmetic. Penrose (1989) seems aware of the unprovability of the falsity of not G (F) (p. 140): his

demonstration is more concerned with establishing the truth of Gödel's theorem using a particular formalism than anything else. Yet Sloman's point about the non-standard systems is a palpable hit.

Penrose goes on to argue that the type of non-algorithmic decision-making which decides on G (F) is *a fortiori* a function of consciousness. In this, remarkably, he finds himself at one with Baars (1988, p. 75). For Penrose, mathematics is above all about meaning (p. 146). Any attempts to justify the inference in terms of the development of increasingly encompassing formal systems is mathematically dubious (p. 143; see Johnson-Laird's work, above) and above all, misdirected. The truth of this and other such mathematical propositions can be established only by means of a "reflection procedure" (p. 145).

It is now that Penrose waxes mystical. Critics have tended to identify his position as Lucasian, a charge he rebuts with some ease. Consciousness, Penrose argues, is in fact direct contact with a Platonic form (p. 554)! (Perhaps his many hostile reviewers might have been better-advised to take him on in philosophy, rather than his home ground of mathematics.)

There is something inherently attractive about this idea, yet one can refute it quite easily. Is one's consciousness of this book actually of an ideal such book which it poorly reflects? The attractive point is that consciousness must eventually be of objects in the external world which it re-creates in intentional form. All that the cognitive and computational schematizations have given us is the results of internal processes constituting consciousness.

Penrose's main concerns relate more to describing consciousness in the physical terms of "wave-function breakdown" and spelling out the algorithmic consequences. His work is extremely worthwhile for its range of reference, whatever about its correctness.

8.1.4 Summary

Let us take stock. We may conclude that the following constructs are useful for any description of consciousness:

1. The notion of process.
2. Baars' five requirements.
3. The notion of consciousness as an entity which can be at least slightly causal.
4. Consciousness as a non-algorithmic, relatively slow, decision process.
5. The fact that consciousness is, inter alia, intentional i.e. directed at objects in a world at least conceived of as external.
6. Selfhood, consciousness and perhaps also will are interrelated.
7. One may have grounds for positing different types of consciousness for logico/mathematical objects to normal consciousness.
8. Consciousness often is of the past, rather than the present.
9. Selfhood is in some sense created.

8.2. What is at stake?

It may be as well to remind the reader of precisely what is at stake in this discussion. At first glance, the following issues seem to have emerged.

1. The existence of a "soul" or dualist "self-conscious mind" (Eccles, 1987).
2. Moral responsibility.
3. Consciousness and its relationship to the world.

Yet the situation is even more fraught. The theories we have reviewed have found it essential to include will and selfhood in their discussion of consciousness. There is even more at stake than we might immediately discern.

Cushman (1990) is concerned with the notion of selfhood, as it has historically unfolded. For Cushman, the concept of self is historically_conditioned: "By the self I mean the concept of the individual as articulated by the indigenous psychology of a particular cultural group" (Cushman, 1990). Moreover: "The self, as an artifact, has different configurations and different functions depending on the culture, the historical era, and the socioeconomic class in which it exists" (ibid).

We may note in passing that for Karl Jaspers, this chameleon quality is the most perplexing feature of self. For Jaspers, "Existenz" is "that capacity of our self for free decisions in virtue of which the self is inexhaustible by scientific knowledge, not because it is too complex to be fully described, but because there are no limits to what it can make of itself" (Passmore, 1966, p. 473). Let us return to Cushman.

The major argument in Cushman's article is that the present configuration of self is the "empty self" as distinct from, for example, the Victorian "sexually restricted self" (Cushman, 1990). The "empty self" is prone to abuse by "exploitative therapists, cult leaders and politicians." Psychology is to be castigated for playing a role in "constructing the empty self and thus reproducing the current hierarchy of power and privilege" (all quotations from Cushman, 1990).

It is regrettable that Cognitive Science may also be to blame in this regard. The viewpoint criticized by Cushman can be seen also in Baars (1988) and reaches its nadir in Minsky (1987). For Baars, self is merely a level in the "context hierarchy." For Minsky, the concept is more fugitive: "We construct the myth of ourselves" (Minsky, 1987, Section 4.2). Yet the constructor of the myth must also be in some sense identical with the myth! The only framework in which a notion like Minsky's works is the one like Jasper's, which makes the self, as we have seen, inexhaustible by scientific knowledge. Of even more significance are the cultural consequences of such an empty self theory, which are negative in the extreme. The final point that must be made is that in the light of Cushman's view of self, Minsky has chosen one from a possible multitude of configurations of self and proposed it as the only valid one. His theory of self, as stated, is not just ethically questionable, but scientifically incorrect. The hand-waving we have noted in Dennett's (1992) popular book is another such example. Indeed, in its conclusion he admits that he has not explained consciousness, despite the book's title (pp. 454-55) but has supplied a new set of metaphors.

The neurophysiologist Blakemore (1988) we've seen in chapter 5 in another popular book based on a TV series, insists that we consider our notions of consciousness,

selfhood and free will simply as convenient fictions, genetically engendered (p. 272). This is not a scientific hypothesis of any description: it is simply an assent to the prevailing "empty self" culture dressed in evolutionary clothes. Dennett (1990) similarly attempts to deprive us of "intrinsic intentionality," while offering as little cogent argument as Blakemore and Minsky.

When it comes to discussing notions like self, Cognitive Science must begin to examine its own culturally_conditioned origins. The alternative is that it merely assents to the Zeitgeist, while erroneously claiming objectivity and scientific corroboration. The consequence is not just incorrect scientifically but destructive ethically. We shall later look at features of selfhood which give it the labile qualities which Jaspers notes. This analysis is a Cognitive Science enterprise in that it considers social factors as entities to be processed, rather than sui generis (Gardner, 1985). It is argued that, even in these restrictive terms, the views noted above can be seen to derive from a common mistake in the importation of computational terms. It will be argued that selfhood, considered in the abstract, does not have this or any other fixed type of architecture. In keeping with the trend of this area, the argument is extended to treatments of consciousness and Will. (This argument is reiterated in a sociological context in Ó Nualláin, in press).

8.3 Consciousness as treated in Philosophy

8.3.1 Analytic philosophers discuss consciousness!

Yes, it does merit an exclamation mark: consciousness spent a lot of time in limbo, along with angels, God and other topics which were sheer bad manners to discuss. Dennett we have looked at: his intriguing comment that no_one is conscious may be nearer the truth than much of the rest of his book. Let's examine the work of Flanagan and Searle.

On Libet's (1985) findings, Flanagan (1991) has much to say. In fact, he interprets them as indicating that: "Conscious processes play variable but significant causal roles at various points in different cognitive domains" (p. 348).

For Flanagan (p. 364), consciousness is a "heterogenous set of events and processes that share the property of being experienced." It is essential to human nature (p. 365). It above all involves awareness (1992, 31); it comprises, inter alia, "qualia" which are experiences with "feel" (1992, p. 61). He is at pains to argue for the real existence of qualia. Again, self is a center of narrative gravity (1991, pp. 345–5). One may decide to present one or other of one's possible such centers.

The arguments against Baars' position on consciousness below apply also to Flanagan. Similarly, his view of self needs to be reviewed. There is a tension in his later work between a notion of self as fragmented and Polonian advice on being true to oneself: "your life will go best when this is so" (Flanagan, 1992, p. 211) He uncontroversially suggests that the methodology used for consciousness research should combine first person reports, psychological models, cs (which he has astutely always been very careful to characterize in informational terms) and neuroscience. His major contribution is his inveighing against those obscurantists who insist that we can't study consciousness in a naturalistic way. When the name_calling and invective has subsided, it is hard to be convinced of Flanagan's argument. Consciousness

research will certainly extend our conception of valid scientific method; in fact, Flanagan's "method" is such an extension, as is Dennett's. What is lacking in Flanagan is the same as that in Dennett: a satisfactory theory of

Consciousness. Both are homuncular theories: in one the homunculus is computational; in the other it is evolutionary.

The same lack of a satisfactory theory of Consciousness is true of Searle (1992), despite his brilliance as a destructive critic. He proposes a new science to supplant Cognitive Science (p. 228):

"The study of mind is the study of Consciousness." It has been argued throughout this book that CS must be extended to include consciousness; however, it is hard to see Searle's minimalist proposals (pp. 247–8) as a sufficient foundation. He is honest enough to admit that Consciousness does not fit into the current scientific worldview; he compares it to electromagnetism before Maxwell (pp. 102–4). I believe this to be an understatement.

Searle wonderfully describes the process whereby standard texts on the mind bully the reader into accepting a form of materialism by offering Dualism (and, presumably, the Spanish Inquisition) as the only alternative. He goes on to argue that materialism is philosophically incoherent (p. 53). Consciousness, he argues, is ontologically irreducible, with the consequence that it is something which must be explained in terms other than those which currently obtain. He posits a set of features of Consciousness : its unity, mood content, aspect of familiarity, etc (p. 127ff). At this point the analytic Searle has become a hobbyist phenomenologist. We shall review the work of Merleau_Ponty, a full_time one, presently.

8.3.2 ... As does everyone else

Above, we reviewed some computational, mathematical and cognitive views on Consciousness. Dennett's has been criticized for its substituting for the Cartesian homunculus the "deus ex machina" of a Virtual Machine. Johnson-Laird, in a similarly inappropriate fashion, appeals to the notion of an operating system. Jackendoff's formulation of conscious inessentialism lacks any strong evidence to back it up. Flanagan's schema is an exercise in evolutionary speculation, interesting in itself but unproven and perhaps unprovable. Penrose's Platonism requires a great deal of philosophical argument to support it and this Penrose does not supply! Cushman has alerted us to the urgent nature of these issues.

To introduce an alternative view, we will look at just on issue; how can we say that consciousness constitutes the world, and yet avoid solipsism? The answer is that we cannot say so at all if we reduce consciousness to mere qualia (Ayer, 1982, p. 219). Consciousness assumes, a priori, the existence of one's own and other bodies. "It is through my body that I understand other people and things" (p. 220).

In his account of Merleau-Ponty, Ayer (pp. 216–221) agrees with the French philosopher that a child must start from a concept of Being itself which includes:

1. the embodiment of self and others.
2. the consciousness of others.

3. the existence, *a priori*, of objects set apart in space in order for any cognitive development to occur.

Nor is it by any means a solecism in philosophy to insist on this primordial intent toward Being: it can be found inter alia in Brentano, the originator of the term "intentionality" (Passmore, 1966). Baars' formulation, for all its rich range of evidence, limits itself to Consciousness as a process and lacks this connection with Being itself.

An enormous literature has grown up about the historicity of the notion of selfhood (Cushman, op cit; Taylor, 1989). The major current difficulty with the concept is the poverty of the current philosophical vocabulary used to discuss it. The task of the remainder of this chapter is chiefly to continue to argue on Cognitive Science grounds alone that this discipline is making the same mistake, and to argue, again using only the type of evidence which Cognitive Science allows, that, as a cognitive construct, selfhood is altogether too fugitive a construct to lay on any Procrustean bed of computational theory. It is with selfhood that Baars' framework collapses.

While castigating the dearth of philosophical vocabulary as noted above, Taylor (1989) points to three characteristics of selfhood which yet endure:

1. The notion of depths within the self
2. The affirmation of ordinary life which emerges
3. The notion of selfhood as somehow still embedded in nature

The argument here is that Taylor's critique and positive recommendations are correct, but that the importation of such considerations into the Cognitive Science/AI framework first requires a perceived inadequacy of this framework *in its own terms*. By now, this perception comes easily to us.

8.4 The Development of Selfhood

8.4.1 The paradoxical nature of selfhood

One way to find the self is by dividing ourselves into subject and object in the manner we saw in chapter 1 that Hume (1896) recommends. Here, the regress is infinite. We came to a crucial paradox: we cannot find self as an object. This does not call its existence into question; rather, it calls into question the applicability of normal objective observation in this field of study.

Our second path was to attempt to find self in terms of its contents. We noted that Baars (1988) considered self could be found in terms of its "context hierarchy." Self-ideals, self-image as well as notions such as the physical self might constitute it in these terms.

Yet here, once again, the regress is infinite. As we attempt to abstract self and grasp it by separating it from its contents, we realize that nothing seems to remain. Jasper's notion of "Existenz" now seems a profound one.

"Self" is, then, an extremely fugitive entity. It can be the unity of the person, and extremely severe brain-ablation cannot infringe this unity, even when combined with an extremely contrived experimental setup (MacKay, 1987) (see chapter 4). It can also

be that "bunch of monkeys" we see when we introspect. Obviously, a new vocabulary is necessary; (Ó Nualláin, et al, 1997) provides it in detail. It's outlined here presently.

It cannot be an object, or discovered through ordinary introspection, as Hume found. Nor does any attempt to identify it with any mental content succeed. Part of its essence is its own tendency to identify, as described by Jaspers (Passmore, 1966). Its tendency to identify can transform mental life, and in this sense the notions of will and consciousness are causally dependent on the self-concept (Cushman, 1990).

It is time to make a few crucial distinctions. If you have attempted the Nolanian Meditations and tried to find self as an object, your target was the "punctual" self. That which Cushman focused on was the "individual," a cultural and linguistic artefact. We shall upper-case the "unity of the individual" and call this the "Self." That which maintains subject/object distinctions, as noted later, we term the "cognitive" self. The "Self," that which has moral responsibility, is unitary. Only in the case of "multiple personality" psychoses is the individual multiple. The cognitive and punctual selves, intricately interrelated as they are, are both legion; we have myriad such. The problem with CS research is that they are in turn confused with the individual and the Self. Each of our cognitive selves may have its own memory, in phenomenological terms. As you read these outlandish words, here is a thought experiment; try and remain the same "self" as you retrace, step by step, how you got to work this morning, including the thoughts that went through your head, the associations evoked by the familiar locations, etc! For the remainder of this chapter, unless explicitly otherwise noted, we use "self" in its cognitive sense. As a hint about the overall theory of cognition and its development to be outlined in chapter 9, it is appropriate to say that the cognitive self is context-dependent; its state of development is an index of the distinctions present in consciousness. As cognitive scientists, it is the only phenomenon of selfhood we should be concerned with. (Orthogonal to this is the degree of development of the "individual," best thought of as a function of the quality of inter-communication of these "selves" (rather like an AI agent architecture!), and perhaps best labeled as that person's "level of consciousness.")

8.4.2 The origins of selfhood

Minsky (1987), in one of his frequent visionary moments, ventures into the area of ontogeny: "We start as little embryos, which then build great and glorious selves" (section 4.3).

Let us first review one argument in this book: The nature of self is in essence paradoxical. Yet this fact may appear paradoxical only because our objectivist approach is incorrect.

Certain characteristics of self which render it inexhaustible and unobservable by and in the current cognitive science paradigm are pointed out above. Lasch (1985) and Cushman (1990) both comment on the cultural boundedness of any such paradigm. More importantly, Cushman goes on to argue that there is considerable danger involved in falsely pretending to have a coherent view of notions such as selfhood.

I believe that will, consciousness and self are interlinked conceptually as well as in their ineffability. I consider this interlinkage to be best demonstrated by looking at the

ontogenesis of self. The **forthcoming** account is prescription as well as description. It is an invitation to see one's own mental life in a certain manner as well as an objective description thereof. It has been argued above (Cushman, op cit) that this is inevitable in any description of selfhood. The theory will be outlined, followed by its relationship to the known facts.

8.4.3 An alternative perspective: the self and its world

We start life with a global notion of self, a self which does not acknowledge any differentiation between the physical body and the world. Nor has consciousness begun to be filled with the later categories which make intellectual life possible. What is the normal adult state?

For Brown (1977), "consciousness corresponds to stages in the development of the object world" (p. 150). Adult consciousness makes fine distinctions between perceptions and concepts, but only in the areas in which the person has expertise. We all have expertise in the physical environment (Piaget, 1960); however, attunement to legal objects, for example, requires the requisite training in law.

The notion of "process" (but not of operating system) is a useful one here. The normal adult state is that there should be a multitude of processes, with the great majority of these automatic. Consciousness resides at the process with the greatest number of degrees of freedom, or else is dulled by daydreams. (William James's caveat about the different types of consciousness separate only by the "filmiest of screens" is being ignored on an "as if" basis. We are concerned here only with normal waking consciousness, as outlined by Baars,)

And self? Brown (1977): "The separation of the world leads only to a consciousness of the world and of self qua object in that world. Self awareness requires a further differentiation within self" (p. 151). Brown, though accurate, does not have the vocabulary to express this properly; see above. By self-awareness he means the "punctual" self.

Self is normally a fugitive "tacit" rather than an "explicit" experience (Polanyi, 1958). Only when will is in operation does the experience of self become less blurred: "Will is a prominence of self in the context of an action (or an inaction) " (Brown, 1977, p. 152).

In the phenomenological notion of authentic existence, according to Thinès (1979), the true nature of one's subjectivity is co-revealed with the object to which the will is directed. Thus, Brown's interlinking of will, self and the consciousness of an action has a phenomenological counterpart. Johnson-Laird (1988) we have seen attempt a similar linkage through the notion of "model" in Cognitive Science.

Selfhood, then, is revealed as we leave the shelter of past experience. Johnson-Laird (1988), who often has a strong line in common sense, comments on the differences that can exist in strengths of will. In the schema here, that strength is related to one's striving to objectivity, and thus to authentication of selfhood.

We also have a contradiction of Minsky (1987): "Consciousness does not concern the present, but the past: it has to do with how we think about the records of our previous

thoughts" (p. 150). This needs expansion: what Minsky talks about is only one of the modes of consciousness. As objectivity, consciousness is qualitatively different.

This theory is obviously also a new perspective on individuation. A pre-articulate striving to objectivity, and with it authentication of Selfhood, is the dynamo of mental life. Moreover selfhood seems to consist in the accumulation of these moments of its co-creation with the subject's particular world of objects. The consequent conceptualization of the world is embedded in, and largely constitutes, the individual's consciousness. "Consciousness is a manifestation of both the achieved cognitive level and the full series of cognitive levels at a given moment in psychological time" (Brown, 1977, p. 150).

Consciousness, will and selfhood are not epiphenomena of mental life; they are its core. Together, they define the computational processes which take place, and constrain the operations of the "machine." Human life is a fortiori a process of self-authentication. (Even in the cases of severe brain-ablation the Self and its will are unitary (MacKay, 1987)). Moreover, there is no commitment to either a materialist or a dualist ethos in this theory. On a technical level, the urge towards Self-authentication means that formally equivalent human and machine systems will differ in that the former must by its very nature, in a way mediated by affect, consciousness and selfhood, seek to extend its range of competence. On a metaphysical level, the central paradox is that the human subject continually attempts to realize its nature as an object in the world. The classic discovery of Archimedes (Lonergan, 1958) came from one such realization. Again on a metaphysical level, the stable relationship of subject and object that GOFAI requires becomes much more fraught, and cannot be considered in full apart from the unfolding of the person in their full individuality.

8.5 The minimal requirements for this theory

8.5.1 The essential constructs

It is fair to say that Baars takes some pride in the economy of his theory: there are only three entities required, i.e. specialized unconscious processors, a global workspace and contexts (p. 359: also see above). Baars' schema has been commented on. For the moment, there is a pressing need for some explanations.

In fact, there are fewer assumptions than might immediately seem to be the case. Here they are:

1. An external world.
2. The "self" quite simply as a process of identification, which may identify with anything (or nothing).
3. A unified will which can direct consciousness outward (or unify a fragmented system of selves), when so directed.
4. Consciousness as, inter alia, intentional re-creation of the external world.

The first might seem an extremely controversial assumption. However, it is impossible even to start thinking about consciousness without relating it to an external world. If the theories described above in section 1 have taught us anything, it is surely the inadequacy of investing for example mathematical and logical certainty in the

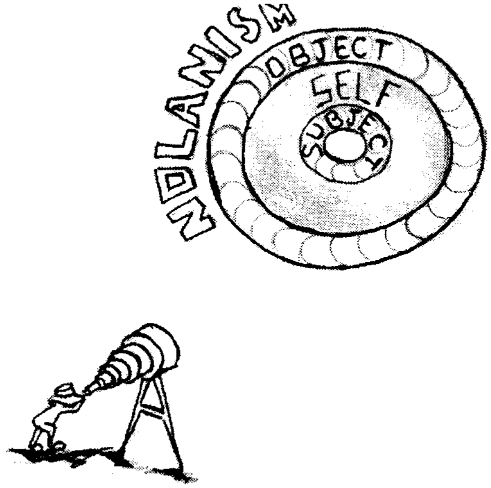


Figure 8.1

operations of a virtual machine which receives necessarily incomplete input only from processors. Moreover, how can one square this "pandemonium" notion of consciousness with its role in intentionality? We have throughout this book referred continually to the different types of objectivity possible, i.e. the different "theories" of the external which are necessary for a coherent linguistics or neuroscientist or whatever. Popper's (1974) theory of "World 3," the world of our cultural artifacts, is relevant here (see Nolan, 1990).

The individual may be fragmented, unitary or non-existent according to the prescriptions it receives. In a healthy culture, its identifications are indeed at lower, more constant levels in the context hierarchy. However, it is thus directed by the functioning of will, the parameters of which are also set by the society. Thus, it is doubtful that the techniques Baar proposes for self-control (see above) can actually work due to their own culturally-conditioned genesis.

It is frequently pointed out (e.g. Flanagan, 1991) that the origins of selfhood lie in immunology. It is necessary even for bacteria to recognize foreign bodies. This argument may be extended to the Cognitive level. Once a mis-identification with the external is corrected, the function of self in this context is to preserve the subject/object distinction thus uncovered (see figure 8.2). For example, it is impossible for Archimedes ever again to fail to notice the water rising. Moreover, the Eureka moment is the epitome of consciousness; it is the task of will to direct attention toward the external world to maximize the number of such moments.

Perhaps the confession by Dennett at the end of *Consciousness Explained* (pp. 454–5) that he has not explained consciousness is the best note on which to introduce the final point. Consciousness cannot be explained in terms of purely internal processing activity. It is necessarily embodied and situated.

8.5.2 Toward a new vocabulary

It may help matters a great deal if we note the following:

1. Consciousness is quite different from mere "awareness" or "sentience." (English fails us here.) It is possible to point it as another level above sleep/coma and mere waking. Baars' set of requirements for consciousness, correctly in my view, are stringent enough to ensure it is an occasional achievement, not a continual process.
2. Selfhood as subjectivity, as socially conditioned (i.e. the individual), and as a process of identification all need to be clearly distinguished. We may speak about the development of the individual *qua*, for example, historical incidents such as the

Russian serfs' right to stay on the land. However, the underlying processes of identification, and correction of misidentification remain intact.

3. Will is the dynamo of mental life. It involves often paradoxical events e.g. realizing oneself as an object in the world.

8.5.3 Summary

The argument of this chapter to date can be summarized as follows:

1. There is an external world of objects.
2. Consciousness is consciousness of this external world, and develops throughout one's life.
3. It develops most of all through moments of authentic existence, which differentiate subject from object.
4. These moments are remembered because they correct any misidentifications of self/not-self.
5. Cognitive development is therefore also a process of self-authentication.
6. Inauthentic identifications can lead of notions of oneself as empty, fragmented or multiple.
7. Cognitive scientists (including workers in AI) have moral as well as scientific responsibilities in this area. So far it can be argued that we have failed to live up to them, surrendering instead to our necessarily ephemeral cultural context.

8.6 Self as a filter

We're gradually converging on a notion of self as a cognitive apparatus. On an experiential level, it is a process of identification, and in a processing sense of the correction of misidentification. In that, it recreates at a cognitive level what the bacterial immunological response performs at the biological level. It can sift through sensations, labeling the ego-alien material as "nonsense" and the rest as sensible. Authentic existence where subject and object are co-revealed, reveals self as a tacit experience. In the diagram 8.1, the machinery of the "self-service" in authentic existence is the Kantian Categories and other structures and mechanisms which mediate between us and the world (i.e. subject and object): Self is a result, not a Cartesian homunculus (diagram 8.2). We must not confuse self and the epistemological subject.

We have noted, time and again in analysis of work such as Sperling's, that a huge amount of information is neurally processed to some degree. We become aware of only a small fraction of it; the rest is jettisoned as ego-alien. People suffering from clinical autism and thus lacking this filter tend to be unable to cope properly with their environment, despite their vast other skills. Moreover, consciousness and selfhood are also interrelated in that conscious experiences are those which self identifies as non-alien: they are thus learnable, and can be consciously experienced.

The phenomenon called "blindsight" also shows that non-conscious experiences are not learnable to anything like the same extent as conscious experiences. We can, if we like, regard the processing requirements involved in existing socially as people in the world as a RAM disk, a drain on computational resources. Finally, all the above refers

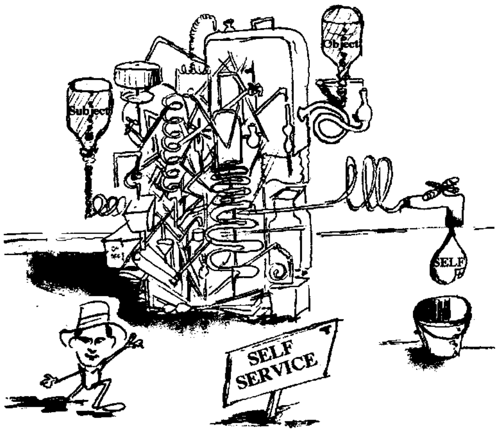


Figure 8.2

to focal awareness. Polanyi's notion of subsidiary awareness is indeed a powerful concept, but any Virtual Machine explanation for consciousness is a little too facile.

8.7 Self and motivation

We have, in chapter 2, looked at Maslow's hierarchy of needs, culminating in Self-realization. This final notion can be considered also as a theory of Cognition. Remember again Archimedes in his bath in chapter 1. Some computational process must have been monitoring his physical impact, in much the same sense as Alexander's WIZARD system (see chapter 4) could become attuned to the patterns of its own firing. This transition between egocentric and intersubjective, once achieved by a process such as Archimedes', cannot except wilfully be forgotten: in the terms of generative grammar, it becomes part of the individual's "competence."

In fact, this type of process may be the crucial core of a new, ecologically valid theory of cognition. Remarkably, it is this most apparently private process of finding oneself as an object in the world which is the most consensually-valid of all. A good education process encourages and indeed tries to provoke this transition from egocentric to intersubjective: the previously somato/motor experience acquires a symbolic context and an experiential context. It is that kind of experience in which we can have coherent discourse, at whatever level of human experience one chooses to mention (from learning to dance to a United Nations Security Council meeting). The roots of consciousness, will and self may be seen in this perception of oneself as an object. Think about it: one is a successful agent in the domain, and truly conscious of the domain, to the extent to which one is aware of one's actions as an object in the domain. (See chapter 9 for a much fuller account.)

Moreover, one may be considered as having free will to the extent that one can actually, having become aware of the consequences of one's actions, halt them. The desire to realize oneself as an object can thus be seen as a generic substratum, underlying self, consciousness and will.

That notion I claim as ecologically valid. The notion of the world of coherent objects as those which can be without fear of contradiction intersubjectively defined allows us to take into account also the transcendent consciousness which was the goal of Husserl's later work. Moreover, once we leave Cartesianism behind in our analysis of selfhood, we may feel comfortable with a Husserlian notion of a transcendent Self, not as a possession, but as an occasional visitor in the field of consciousness.

Then again, we may not. The scheme I have outlined allows different levels of free will in different people, different levels of consciousness between different people and

different domains, and more or less unified overall notions of Self between people, depending on the extent to which they unify their social experiences. At one extreme, we might have multiple personalities and psychogenic fugue (which involves people quite literally forgetting who they are); at the other the (presumably) fully-realized Selves of hermits who allow themselves little or no social contact.

8.8 Conclusions

This chapter began with a review of the theories of consciousness (and, where applicable, of selfhood) offered by Baars, Jackendoff, Minsky, Johnson-Laird, Flanagan and Penrose. Some, such as the "mental models" view, were found inadequate for formal reasons. The others were investigated on philosophical grounds, and in the context of the historically-conditioned nature of the related concept of selfhood. It was found that in several cases they involved prescriptions for the description of selfhood which are unproved and perhaps destructive.

The chapter then switched to the task of giving an integrated account of consciousness with respect to cognitive development. The premise is that a theory of consciousness requires one of cognition which in turn demands one of cognitive development. The distinctions available to consciousness are primarily cognitive achievements One important such distinction is that between the subject and his world, as he conceives it. It is argued that the cognitive function of self, as distinct from the felt experience of self, lies in the preservation of this distinction.

The major points which emerge are the following:

1. Consciousness is at another level above sleep/coma and mere waking.
2. Consciousness is of objects in an world.
3. Consciousness develops, and does so most of all through moments of Heideggerian "authentic existence," which differentiate subject from object.
4. The cognitive achievements of these moments lodge in the habitual structure of the mind, due to the cognitive activity of self noted above.
5. The development of both consciousness and cognition is thus primarily a process of self-authentication. Inauthenticity can lead to concepts of oneself as empty, fragmented or, in the extreme case, multiple.

8.9 Recent developments

The argument in this chapter up to here is programmatic and is oriented to identification of consciousness with a certain remote act of mind. I am fully aware that the word "consciousness" can be stretched in many other directions; consult my contributions in *Two Sciences of Mind* (Ó Nualláin et al, 1997) and the turn-of-century Mind-4 conference (Ó Nualláin et al, 1999). The confusion of tongues necessitating such linguistic trickery and conceptual fiat in order to isolate something – anything – to talk coherently about still continues (see, for example, Shear, 1997). However, glimmers of light are beginning to pierce the fog and we're going to conclude this chapter in their faint glow. I shall then revisit the schema outlined above.

The main problem is that this single word "consciousness" has been given too much to do; it needs less to be deconstructed than smashed into smithereens. Block

(1995) found one worthwhile fault-line therein. For Block, access (a-) consciousness corresponds, roughly, to usability and phenomenal (p-) consciousness corresponds, equally roughly, to qualitative feel. More formally:

"A state is a-conscious if, in virtue of one's having the state, a representation of its content is…

1. poised to be used as a premise in reasoning,
2. poised for rational control of action, and
3. poised for rational control of speech." (Block, 1995, p. 231)

The reportability precondition (3) is perhaps best ignored, particularly for the purposes of the following discussion. Weiskrantz (1997) famously identified a condition called blindsight, in which subjects (rather than patients – the disability was often minor) with lesions to visual area 1 (V1) were able to demonstrate ability to perform tasks at above-chance levels in areas in which they had no conscious visual perception. For example, they could distinguish pictures of two separate sets of objects such as cats and dogs. However, they had no phenomenal awareness of these pictures. In the extreme case, they would have a-consciousness without p-consciousness thereof. (It is as well, perhaps, to note one caveat immediately: the existence of blindsight as a distinct phenomenon is beginning to inspire dissenting mutterings.) There are several lessons that we shall take away from this. The first is that a certain limited amount of learning (implicit learning) can take place without consciousness. For example, regular past tenses can be so processed; irregular ones, interestingly enough, cannot be. Secondly, subjects could not voluntarily access the information in that part of the visual field to which they had a-consciousness but not p-consciousness. It is as if the full extra processing power that consciousness gives must be supplied by means of a voluntary act, which immediately generates p-consciousness. If so, a Darwinian explanation of the origins of moral action might well start from here (see below, and the accompanying volume). Finally, it is possible that of the two informational streams, only the ventral stream has offshoots into the systems supporting awareness; blindsight could be a severing thereof.

At least a crepuscular glow is emitted by Damasio (1999), involving as it does the positing of two other fundamental properties of the brain along with binding, Darwinian dynamics and so on; intentionality and reference to a self. These granted, his schema is neat indeed. Damasio declares himself vehemently against "the naysayers" who argue "that the exhaustive compilation of all these data adds up to correlates of mental states but nothing resembling an actual mental state" (p. 76). (The logical consequence of this is to say, along with Colin McGinn that, for example, Pain = *f* (C-fibres), where we can never understand the nature of *f*.)

Damasio takes his first liberty when he points out: "But brain cells, at every level of the nervous system, represent entities or events occurring elsewhere in the organism. Brain cells are assigned by design to be about other things" (p. 78).

So much for Dennett's intrinsic intentionality; Damasio feels obliged to introduce a deus ex machina.

I cannot resist preceding Damasio's second fiat with a quotation from Kierkegaard's *The Sickness unto Death*: "Man is spirit. But what is spirit? Spirit is the self. The self is a relation which relates to its own self…the self is not the relation but that the relation relates to its own self…" (Kierkegaard, 1941, p. 17).

For Damasio (1999, p. 79) is about to make a similar move:

> "The brain uses structures designed to map both the organism and external objects to create a fresh, second-order representation… it presents within the mental process the information that the organism is the owner of the mental process."

We noted at the end of chapter 4 how Damasio naturalistically explains how we find ourselves in a multi-modal world as stimuli impinge on us from various parts of the cortex. Where, precisely, "we" are at the time is discussed below. (An interesting pathology here is simultagnosia, with a complete lack of recognition of all objects, but a sense of self.) Now he has cracked the second enormous issue, that of the reality of the self, at least to his own satisfaction: "Objective brain processes knit the subjectivity of the conscious mind out of the cloth of sensory mapping" (ibid). Metzinger (1999) finds another stream of argument in Damasio's work: a distinction between core consciousness and extended, autobiographical, consciousness which is yet "ceaselessly re-created for each and every object with which the brain interacts" (p. 101). Both, he argues, are implemented through the cingulate cortex, which has the necessary hardware to do the mapping described above; significantly, it is not involved in wakefulness, which can be induced by a remedy as simple as acetylcholine applied to the brainstem:

> "Consciousness and wakefulness, as well as consciousness and low-level attention, can be separated. Interestingly, what cannot be separated are consciousness and the emotions" (p. 102).

Paradoxically, the core self and "proto" self are located in the upper brain stem and hypothalamus, and lesions thereto cause pathologies in p-consciousness. We can safely bracket these localisations, while acknowledging that, his liberties granted, Damasio's is an imaginative and worthwhile schema.

Baars' (1996, 1997, 1999) thought has also developed. He now sees consciousness as a spotlight, directed to a point on stage by attention. It integrates multiple sensory inputs and disseminates them to a "wide audience" of different modules within the nervous system. The primary function of consciousness is to provide a global workspace, which Baars mistakenly identifies with a blackboard. Doris et al (1999) indicate that Burnod's columnar automata might provide a more hospitable and neurally plausible computational formalism. Consciousness above all gives access to computational resources; limitations on implicit learning are transcended. In Ó Nualláin et al (1997, p. 294) we saw the Baars school argue that the seat of subjectivity might be the nuclei reticularis thalami (nrt). Baars has since been very impressed by the work of Sheinberg and Logothetis (1997), Logothetis, 1999), which he considers Nobel

calibre [personal communication]. By careful differential presentation of visual stimuli, these researchers determined that a number of cells in the inferotemporal cortex fired only when the subjects were conscious of particular stimuli.

This has been sufficient for the Nobel laureate Francis Crick to determine that here is the holy grail: the neural correlate to consciousness! (in Wilson et al, 1999, p. 194). The holy grail of Crick's autumn years having been found, he is now open to discuss whether consciousness is a property of a particular type of system; and, no doubt, the Nobel winner who gave respectability to the panspermia hypothesis of the origin of life might be willing to discuss the Whiteheadian speculation in our companion volume about whether consciousness is a basic property of the cosmos as a whole.

Consciousness is moving fast (at least four locations so far in this book), so it is almost a relief to describe a debate that perhaps has slowed the field down over the past decade: that between the "hard" and "easy" problems (Chalmers, 1997). For Chalmers (op cit, p. 389), "the facts about consciousness do not just fall out of the facts about the structure and firing of neural processes." There is an explanatory gap from these processes to the experiential level, a hard problem; neural process is relatively easy. I discuss Chalmers, and the origins of the explanatory gap argument in Joe Levine's work, in the companion volume. Damasio's is a neat counter. (Further philosophical solace for Damasio is also provided by Kant's assertion that self is a category, an inevitable instrument for cognizing the world.) Baars (1997, p. 244), certainly the most creative cognitive researcher in this field, disputes whether this rather overdone distinction can long be sustained: "Consciousness is always accompanied by subjectivity. It appears therefore that far from being separate from information-processing functions, the 'hard' problem interpenetrates what are said to be easy problems!" Or, in LaBerge's (1997) terms, awareness always involves the representation of self. Where Chalmers is particularly good is as a critic of others' ideas. There is some wonderful writing on Dennett: "The key lies in what Dennett has elsewhere described as the foundation of his philosophy: third-person absolutism… to shift perspectives like this – even to shift to a third-person perspective on one's first-person perspectives, which is one of Dennett's favourite moves" (Chalmers, 1997, p. 384).

However, Chalmers (op cit, p. 392) is willing to grant that "the issue between Daniel Dennett and myself…comes down to some basic intuitions about first person phenomenology."As I argue in *Being Human*, it is possible that Chalmers has a more differentiated access to his experience, as subject to object, than the rest of us.

We shall shortly synthesize the findings so far; the distinctions made earlier in this chapter still hold and we are reconstructing the schema in the light of the new evidence. There is one final port of call: attention. For researchers such as Schacter (1996), consciousness is essentially a Fodorian module transferring sensory data to a (homuncular?) centre which initiates voluntary action. The debate has moved on: Baars conceives of attention as actually moving consciousness from object to object (rather like researchers are moving it between brain locations); Posner (1997) conceives of attention as a control network, roughly co-extensive with voluntarism, which can actually prohibit items and processes from entering awareness. We are conscious when

we dream, argues Posner. However, the thalamocortical network is closed off to stimuli, and we are immobilised. Consistent with Damasio's schema is the fact that the actions and objects in dream states are undoubtedly referred to a self, although moral responsibility has taken a holiday.

With wakefulness comes a completely different set of issues, related to volition. Action must be monitored, and guided along certain paths set by one's society as well as one's own goals and ideals. We learn how to introject outer compulsion and veto certain actions. It must first be demonstrated to us, as children, that the consequences of these actions are the responsibility of a socially-validated self. Now we come to consciousness proper. Attention, which is subject to volition, and like it differs in quantity between individuals, directs consciousness, which is best regarded as a computational facilitator. The paradoxes begin. How does attention know where to direct focal consciousness? Through the action of subsidiary consciousness. Why are certain objects picked out through this mechanism? Because they reflect the core desires of the self, which has an innate urge to equilibrate. Where in the brain is this self, this consciousness, and so on?

Let us make one final port of call: Michael Gazzaniga (1995), who sees our experience as being continually commentated on by a verbal module in the left hemisphere. Indeed, he is willing to say publicly that a large part of our mental lives consist of buying into the self-delusional web spun by the interpreter (see Ó Nualláin et al, 1997, pp. 288–289 for some unexpected historical precedents for this idea and see Sergent, 1990 for speculations about the neural pathways used). However, Gazzaniga (op cit, p. 1397) insists that consciousness is above all conative, a feeling about specialized capacities: "It reflects the affective component of specialised systems that have evolved to enable human cognitive processes."

This will never do. But his notion of the role of the interpreter is sound. Indeed, the interpreter might have an engineering role in that it ensures that our sense of agency never becomes fully dormant, if necessary by attributing actions to it that it never initiated, and that in fact happened automatically.

What set of actions can then be appropriately so attributed? In keeping with the schema of the previous section, the answer is: conscious actions. What are conscious actions? They are actions in which there is evident an assignment of resources by the attention mechanism. There is, at first sight, the danger of circularity here; consciousness is a sign that the organism has assigned processing resources, and thus shown intent. However, legally we conclude that a defendant showed intent, demonstrable by a pattern of behaviour, and was therefore conscious at the time of a crime, and thus legally liable. The circle is broken by a third-person analysis of the pattern of behaviour; we attribute malice aforethought by looking at a series of actions.

We are committing to the idea that maintenance of a state of consciousness requires constant referral to a social self-system, possibly located in the frontal cortex. How is this particular self-system created? There are innate beginnings in an undifferentiated chaos of subject and object, and a stereotyped set of achievements to achieve this differentiation, as outlined above. However, the elaboration of this system, which is a sine qua non for full citizenship, is a social phenomenon. Obviously, lesion to the

frontal cortex should cause the kind of aberrant social behaviour exhibited by the railway foreman Phineas Gage after his celebrated accident.

Are we conscious when we dream? In this schema, we are not. Let us say that we are tacitly aware in dreams and in normal waking; the word "conscious" is still being reserved. What of the self in these tacitly aware states? It has two aspects: we are willing to grant Damasio his insistence that every mental process communicates about itself the fact that it has an owner. (Perhaps we have multiple such owner-agents in the society of our minds, and the communication indexes the particular one; see the Coda to chapter 9). The second aspect is the operation of the "interpreter," in dreams as in waking. Where in the brain is the seat of consciousness? The major empirical hypothesis of this section is that it moves around. Any process connected with the sensory and motor cortices can potentially become conscious as processing resources are allocated to it. (Indeed, there is evidence that the same holds for some autonomic nervous system processes.) The allocation, over a period of time, can result in more neurons being allocated to the process, which then can become automatic; learning how to drive a car is a paradigmatic case. And so the schema of the first edition of this book is still being adhered to.

8.10 Further reading

Of the references given in the course of the chapter, Taylor's (1989) *Sources of the Self* is the most instructive.

9. Cognitive Science and the Search for Mind

9.1 Introduction

This final chapter resolves the themes introduced in the separate discussions to date. First of all, we review the strands introduced in the separate chapters and show where they relate to current controversies within CS. Secondly, we explicitly discuss the views of mind (of various thinkers) which have often remained implicit to date. Thirdly, we discuss what substantial conclusions emerge from the discussion of mind and CS in this book. Fourthly, the future of CS is discussed, and (in the manner of much of the subject matter in this book) recommendations for this future which are both prediction and prescription are made. Finally, we comment on what consequences CS might have for that most urgent of issues: how human beings view themselves.

9.2 Review

I am the proud possessor of an award conferred on me by the graduating Comp Sci class of 1992 in Dublin City University entitled simply the "Just to reiterate that one more time" award. The honor, I believe, was well-deserved: my uncle, a pedant of the first degree, had informed me at the start of my career that teaching was all about "Repetition. Repetition. Repetition." (Some of this is lost in the translation from Gaelic!) Perhaps the review to follow is a little more than repetition: a collection of the main themes from the various chapters in one place will form a whole greater than the sum of its parts. That, to my mind, is the major justification for the study of Cognitive Science. After the introduction, with its brief history of the area and outline of its current bones of contention, we began to concern ourselves with philosophical epistemology. Having discerned surprising affinities with the thrust of CS in the musings of philosophers, we gradually then began to uncover some of the basic methodological issues in CS. The first was the issue of acceptable data. We took this as comprising the computational and phenomenological realms. Unlike philosophers of yore, we can add the neurophysiological also. Associated with this was the criterion for the real in conscious human experience. To this we brought the analytic tool of consensual validation.

The mind-body (ontological) problem entertained us for a while before we began to proceed to the main business of the chapter, which was to set the general parameters for the studies of the various disciplines about to be undertaken. The ontological problem was approached most subtly by Aquinas: it was put into the context of cognition, which is where we want it, by modern existentialists. For them, cognition is being in the world, not a Cartesian, disincarnate process. Therefore, we start with the notion of cognition as being an inevitable result of immersion in a life world. We found

this idea was best formulated by Merleau-Ponty. However, his work is mainly an account of perceptual experience, if a brilliant one. A problem arises which stubbornly refuses to go away: how can we encompass this type of perceptual experience to get her with the kind of apparently insulated (from the world) processes which comprise much symbolic behaviour in one framework? Merleau-Ponty, Piaget, Edelman, Gibson, Brooks… we find this problem continually recurring in discipline after discipline. On the other side, we find that those who stress the symbolic side of cognition (Chomsky, practitioners of GOFAI) have precisely the complementary difficulty to Merleau-Ponty: how to ground these symbols? We have stumbled on one of the major tensions resolved in this book.

Philosophical schools neatly align themselves along each side of the fault line supplied by the problem of objectivity i.e. the relationship between mind and world or, in more technical terms, the degree to which we can have absolute as distinct from relative knowledge of the world. The intellectual operation of decoupling oneself from the world leads to many patent absurdities if the resulting standpoint is taken as the epitome of all perception and cognition. I hope the reader is convinced at this point that it is in fact just one of many possible mind/world relations. A sample absurdity: Berkeley's exposition of the perceptual frame problem allowed him to conclude from our inability to continually update representations, in the manner of early AI robotics systems, that a *deus* (not necessarily *ex machina*) was necessary to explain our intuitions of a stable world of objects. It has been argued throughout this book that this mind/world relation is part of the egocentric domain, handled by mechanisms supplied, inter alia, by neurons in the hippocampus. One "standard theory" of CS supplies another model: mental representations parsed by syntactic mechanisms and then semantically interpreted (Pylyshyn, 1984, pp. 59–60). Yet the range of phenomena this can usefully handle is similarly limited. Indeed, the re are instances when "semantic" relations can be elicited from the syntax itself. Moreover, there are instances, at the other extreme, when a theory such as Riemann's geometry, although developed solely as a mathematical diversion, turns out to be t he most nearly correct model of reality. In natural language, our eliciting of meaning tends to be an often messy mixture of pragmatics, semantics, syntax and lexical knowledge.

We are spending so much time on this point because it is vitally important. Let's spell it out once again: semantics, whether understood as the activity of characterizing the semantic content of propositions in a formalism such as set theory or the mapping onto "mentalese," is not the autocrat of meaning. That role is reserved for a real, conscious human being.

Our historical analysis of philosophy ended with the work of two geniuses, Kant and Merleau-Ponty, whose views of mind we took as indispensable. (Wittgenstein may have been after bigger game than immediately may appear to be the case, and this is discussed in the final section of this chapter.) With Merleau-Ponty, we found ourselves in a framework where consciousness was causal, paradoxical in nature, and characterized from birth by certain distinctions in being itself. The lack of a worked-out theory of cognition that is both symbolic and situated is perhaps the major lacuna in

the combined efforts of these two great thinkers, and the greatest contribution CS can make to them.

Cognitive science should start by insisting that a theory of cognition also requires a theory of the development of cognition, and that the distinctions in the world that fall out naturally for one at a certain level of cognitive development, especially those crucial distinctions between oneself and the world, are the architectural features of the conscious mind. To extend this metaphor, as cognitive scientists we can either focus on characterizing issues like the semantic content of the walls and pillars or, like phenomenologists, we can make the architectural advance of the Greeks and consider the discipline as the organization of space, rather than building materials. Piaget's theory of cognitive development is still the most encompassing. It is, above all, a genetic epistemol*ogy*, and cannot be understood as other than this. Moreover, it is a biologically based approach quite as much as Edelman's is. In both cases, the leap from biology to symbol occurs. In Piaget, it occurs earlier and with less neurobiological evidence, but it is less precipitous for its wealth of psychological detail. Piaget places the child in the *Lebenswelt* of Merleau-Ponty and invites us to witness the development of mind in all its human aspects.

We found time also to consider the role of factors often wrongly considered noncausal in cognition: the psychoanalytic unconscious, affect, and the related notion of the role of myth looms large in other chapters. Perception and cognition have a more dynamic relationship than often is conjectured. Just as a task that initially requires one's full conscious attention can become part of the habitual structure of one's mind, so also in this framework is a process now best considered as cognitive, now as perceptual. Edelman's work describes this habituation in the terms of re-entry.

Two other matters, both areas of empirical research, concerned us before time came for a concluding framework to be established. One was the matter of the echoic or iconic image, as manifest in the work of Sperling and Sternberg. This was to lead us to the notion of self as filter discussed in chapter 8. The other was problem solving. The notion of *fine* solutions, the gift of a rho-relation that encompasses subject and object, was epitomized by the perception of symmetry and contrasted with a representationalist view of the same matter. The notion of subject/object differentiation, in the sense of an awareness of one's own cognitive processes as object (and possibly in error; Flavell et al, 1986) we proposed as an alternative to the Piagetian notion of conservation. Children oscillate between two different perceptions (there's more water in this jug because it's fuller; more in this because it's wider) before becoming aware of this oscillation also as part of the phenomenon to be explained.

Moreover, Flavell's description of this breakthrough is also a paradigm case of a leap in consciousness. At this point, it is necessary to provide the promised relationship of these issues to CS. It's an old joke, but a good one: Psychology began by losing its soul (with Hume), continued by losing the mind (behaviourism), and ultimately lost consciousness. Phenomenological psychology with its focus on consciousness (as recommended, inter alia, in Searle, 1992) offers a new framework for psychology. The leaps in being culminating in advances in consciousness afford a new opportunity for

defining the intersubjective domain. They should be grist to our mills. I offer the examples of Archimedes and Flavell.

Years of practice as a computational linguist ensure that I approach the subject in fear and trembling. With the intention, uncharacteristic of this book, of displeasing as few people as possible, a review of the major linguistic theories first was given. A separate strand in this chapter invited the reader also to consider the ten thousand creatures that mediate between linguistics and computation, while also offering a review of computational linguistics. Several substantial issues, relevant to the major thrust of the book as a whole, emerged from both streams. The first, which featured also to some extent in Chapter 2, related to the grounding of symbols. This, I suggested, is their interaction with operational knowledge, as exemplified in Cullingford's scripts. The second is the reaction of syntax and semantics, and we mentioned a phenomenon called sublanguage where the burdens of tasks usually handled by semantics are transferred to syntax. A final issue, that of the nature of context, situated symbolic cognition, and the levels of language, broadened the domain of discussion reached in the journey to the last conclusion. A context, it was argued, is the interaction of the symbolic system with other knowledge. As context becomes further and further restricted, the stratification of language becomes less clear, rather like the way gravity increasingly distorts space time nearer to a massive body (we did mention Riemann!). *Contra* Edelman, that does not indicate that there is no autonomous formal system involved in the syntax of language or any other symbol system. *Pro* Edelman, it is agreed that meaning is a conscious intention, not a byproduct of any kind of formal analysis. In its account of the grounding of its symbols, the chapter steers a middle course between formal linguistics and cognitive grammatical theory.

Lakoff's cognitive semantics is, as Edelman acknowledges, compatible with his own particular neuroscientific thrust. In neural Darwinism we found a correlate to the dynamic principle called equilibration by Piaget, the principle of rationality by other cognitive psychologists, autopoiesis by cognitive theorists in biology, and selectionism in evolutionary theory. This manifestation of mind we can isolate as a major theme also. The brain we envisaged as promiscuous in its embracing of codes of interneural communication. Along with the propositional binary code, we find superimposed (much like the DNA molecule) signals as to the importance, interpretation, and role of a particular message. The result is the possibility of signals at numerous levels of abstraction. Pribram's work gives us the evidence for mild realism, already flagged by Edelman as important, which we need for the maintenance of our belief in systems such as Gibson's. It seems likely, moreover, that the brain works in a "systematic" way that distinguishes form from content when the occasion demands it. If such an exigency does not obtain, it is as unsystematic as is adaptive. Again, we experience a tension between the symbolic and the subsymbolic.

AI afforded us an opportunity, which we did not spurn, of identifying the attribution of the knowledge-level description with mind, and projecting this, in line with some current AI practice, solely to the interaction of system and environment. We discussed the current dominant paradigm within CS; that of computation as cognition.

AI systems, we found, fell into the natural kinds of subsymbolic, syntactic, and semantic. Put another way, given a certain degree of restriction of context and a neat theory of the domain, merely syntactic operations could map directly to the world. In less ethereal worlds, a messy and domain-dependent model had to be constructed. Finally, sometimes egocentric cognition was the best way forward.

The next two chapters, 5 and 6, stated their cases briefly. Ethology reveals countless examples of mind in nature. Ethnoscience led us down the path of attempting to isolate, *in situ*, a particular type of act of mind before reminding us that any given activity is part of a whole culture and reflects it in a microcosmic way. On the positive side, we discovered that humans are serendipitous in their organization of their experience and will adopt whatever schema works. Chapter 7 was a brief interlude. After a quick outline of the main principles that remained intact through the rigors of Part 1, we proceeded to discuss what symbol systems had in common. The distinction between the symbolic, intersubjective, and ontological components also has to hold for a cognitive act in any of these symbol systems.

Finally, we proceeded to the discussion of consciousness, and had to clear the ground first by examining current rival theories thereof. A great part of the task of the current chapter is to outline a theory of consciousness and its development in a cognitive context.

9.3 A theory of Mind anyone?

A myriad views of mind has bubbled under the surface in this book. One's view of mind structures one's view of CS as well as, and much more importantly, one's view of oneself in relation to the world. Let's review the major theories from the time of Descartes onward. The great Frenchman's view is deeply enmeshed in our Western self-concept. We reviewed it in Chapter 1. A minimalist view of mind is provided by David Hume, and we'll let the Scot himself speak: "Mind is a bundle of different perceptions which succeed each other with inconceivable rapidity and are in perpetual flux and movement" (Hume, 1777, p. 252).

Kant's view of mind was that of categories mediated by schemas in their relation to the world. As a result, he is sometimes said to risk subjectivism, (the reduction of knowing to purely psychological processes). This is in contrast to scholastic views, which saw mind and object somehow being mediated by a "fantasm" of the object. Phenomenology, on the other hand, grounded its description of mind at the point at which there was no differentiation between subject and object. Consciousness was primary: we arrived at a theory of mind through its analysis. Merleau-Ponty is perhaps the finest thinker along these lines. His concern with the greater issues of being itself surpasses attempts to consider consciousness as merely intentional-that is, only as directed toward specific object.

At around the same time as the beginnings of phenomenology, James was producing another theory of mind whose computational expression dominates current thinking. Mind is a set of functions. The CS view of mind as programs running on computers, the details of the architecture of which are irrelevant, is a direct descendant

of James' views. So too, Fodor's modular mind is a Cartesian offspring that has sloughed off the dualism of its parent.

Finally, two recent views. Edelman insists that by ignoring the hardware, CS has assured its rebirth in one of the hellish worlds of ignorance. The current AI position is that mind is the observer's attributions of knowledge in her observation of system and environment together. And so on, and so on…. There are literally thousands of variations on each of these themes. Our theory of mind will necessarily also be a theory of cognition (and vice versa), and we shall try to found a cognitive science on this. Yes, we are approaching my overall perspective: Much conceptual confusion vanishes if we view CS simply as the science that deals with cognition and refuse to stake its future on any single paradigm, computational, neuroscientific, or grammatical in inspiration.

More details later. Let's just say right now that the following **are** certainly true:

1. Mind is manifest in the adaptation of a species to an ecosystem over time.
2. Yet this is not in itself sufficient. We need a new set of categories in conjunction with the first point to explain

9.4 Foundational considerations

In chapter 7, we glanced briefly at the themes that survived the analysis of the separate disciplines in Part 1. The task of this section is to give further details of the surviving framework, and then discuss the nature of cognitive science in this context. Here, therefore, are the pillars:

1. Mind (and cognition) is manifest in the adaptation of a species and an environment over time.
2. At the individual level, we can usefully discuss cognition only in terms of the organism's being enmeshed in a life world. The adaptation at an individual level is best treated in cognitive psychology via a principle of rationality and in neuroscience through a competitive principle of some sort. The paradoxical dynamic that compels the organism to seek stability in and yet increased mastery over the environment can be termed "equilibration."
3. The focus of study of cognitive science is the combination of organism plus environment over time.
4. In the case of human cognition, a separate set of categories must be introduced to allow for symbolic behaviour. In particular, we need our framework to have the capacity to ground symbols. Moreover, a theory of situated cognition requires that the causal role of context must be both defined and explained.
5. Two sets of distinctions emerge in the analysis of human cognition. In the first place, we can distinguish between egocentric and intersubjective cognition, the latter of which also admits of an autistic mode. (It might be conjectured that the autistic mode is nonconscious egocentric mentation in an intersubjective domain.) Second, we can distinguish between symbolic, operational, and ontological dimensions in human use of any symbol system.
6. Context now can be explicated. In the first place, all cognition is contextual. In symbolic, intersubjective behaviour, context relates to the interaction of the symbol

system with other types of knowledge. (Context is handled by specialized neural hardware in egocentric mentation.) With restriction of context, the interactions between the layers of the symbol system become altered; in effect, the layers compress.

7. Consciousness is best treated in terms of its development and as comprising critical moments of subject/object differentiation. Through these moments of authentic existence, the relationship of subject and object is enriched. The dynamic impelling one out to the world to enrich the distinctions in one's consciousness is the experiential correlate of equilibration.
8. A crucial such distinction is that between the epistemic subject and the world. The cognitive function of self in maintaining subject/object differentiation must be distinguished from the felt experience of self that is most valid in authentic existence. There may also be a form of authentic existence in quiescence. It is at this point that CS must hand over to consciousness studies.
9. Affect has a causal role in cognition. It must therefore be included in cognitive science.

CS ultimately focuses on the cognition of the individual. In order to characterize this, we need some way of distinguishing cognitive Act 1 from Cognitive Act 2 and find we can use the resources of information theory to do this. *Pace* Searle, this does not commit us to buying into a notion that the information-processing level is a privileged one, nor to bracketing the neurophysiological level. Cognitive science is one of a federation of sciences of mind and seeks to be informed by the others, while maintaining its focus on the cognizing individual. For example, it accepts that sociology (Aron 1965) identifies trends in the society using its own methodology, but CS considers only how these present themselves to the individual. It accepts that depth psychology and consciousness studies reveal much about the mind, but waits until an informational characterization of their results obtains before incorporating these results. To do CS properly, one needs to know the basics of those sciences of mind that are peripheral to it as well as the main findings of those that are central. This pluridisciplinary approach, forbidding in scope though it is, is the only one that will pay dividends in the long run. The history of twentieth century thought is strewn with the corpses of previous inadequate approaches.

Along with the central and peripheral disciplines come the antagonistic. The central include cognitive psychology, epistemology (CS can claim to be the experimental wing), cognitive linguistics, cognitive neuroscience, AI, ethnoscience, and ethology. I regard the material in this book as the minimum one should know about these disciplines. The peripheral, at which we also had to glance, include sociology, phenomenology, neuroscience *per se*, and so on. The antagonistic will always include messianic figures, often coming from distinguished careers in other disciplines, who seek to impose their own Weltanschauung on the study of mind, and are less consequential than, for example, the philosophy of mind, which often attempts to do from a priori grounds what CS is doing also using experimental tools. So-called evolutionary psychology is often touted as a similar alternative.

But cognitive science is about computation! All cognitive and perceptual processes can be phrased in the vocabulary of computation, given the emptiness of the original concept. The problems arise when, however ingeniously, an attempt is made to construct a more elaborate language with this vocabulary and to express the whole domain of cognition with it (Pylyshyn, 1984).

But a theory of cognition must have solid biological foundations, and the standard CS theory makes erroneous assumptions both about the reaction of mind and world, and the hardware independence of mental processes! True, it must have biological foundations, and Edelman (1992) may win that particular argument. However, we lack sufficient neuroscientific data for explanation of higher order cognition and certainly don't know anything substantial about how massively complicated symbol systems are implemented.

Therefore, for language, that most essential of human faculties, the formal linguistic description (in some version or other) must take precedence! Or, the activity of CS itself is embedded in a specific culture and we need a well worked out anthropological theory to understand it. Alternatively, the personal motivations of researchers must be thoroughly researched in terms of their early experience to understand the form of their theories! There is a great deal of truth in every one of these positions.

In a sense, CS has always existed. In the nineteenth century, we can trace a science of mind (and experimental epistemology) defined by psychology before the domination by information theory, broadly defined, computationalism and now, possibly, neurobiology. In other words, the subject was, is, and always will be: A change in the dominant paradigm of the area is not its death knell. So let us continue, with open minds and a willingness to admit at any stage that our pet area must take a back seat for a while, to study this bewilderingly complicated and fascinating super discipline, which, as is argued here, is but one of a loose confederation of sciences that together may tease its secrets from mind.

9.5 Coda: the Nolanian Framework

Let's start by just recapping the view implicit in the book so far. The child is born with much innate equipment into a world in which the distinction between subject and object is much more primitive than the adult state will be. The first interactions of the child with the world are generalized from and so image schemas are generated. Later on, the symbol systems will interact with these schemas and other operational knowledge, creating contexts. None of these processes need be conscious; this realizes itself in explicit distinctions of self from world.

The function of self is to maintain subject/object distinctions. It also filters out noncontextual material to facilitate cognition and may have a role in memory in that to remember an event is to index the "I" who was there at the time. Integration of these "I"s is achieved by different people to different degrees.

Symbol systems allow construction of propositions that go well beyond our immediate sensorimotor experience. Some of these extensions are indeed metaphorical transfers but some are not. Incredibly, we find that reality can impress itself on our most complicated symbolic expression as on our egocentric behaviour. As it does, its

distinctions impose themselves on consciousness in an immediate way and for a reason that biological evolutionary theory may have to struggle to find. Why should we be able to know any- thing about the subject matter of general relativity? What possible biologically adaptive role can this have? In a sense, this does not belong in this chapter, or perhaps in this book. Yet I regard it as intellectually dishonest not to outline what change might arise in our self-image from the study of CS as proposed here.

In the first place, it immerses the body/subject in a life world with other people right from the beginning. The environmentalist overtones in this phenomenological starting point are obvious. What must be dwelt on are the social implications. As a person among persons, one is committed to moral decision at the very least as manifested in authentic existence. Second, it posits a causal role for affect and its education. With this, we find ourselves in the realm that is dealt with in a good arts formation.

CS is, *inter alia*, the science of knowing, and ultimately should tell us the distinction between what we know and what we think we know. One interpretation of Wittgenstein (Needleman, 1982) distinguishes between his two phases in terms that will serve to semantic interpretation program of CS; the later is studying the ways in which, through language, we refer to ourselves inauthentically and fail to real-ize ourselves. We might find a lot of our experience to be unauthentic. Conversely, we might find the doors opening for new and beautiful ways of experiencing ourselves, others, and the world.

Finally, a re-emphasis on the primacy of consciousness and the experience of selfhood will be salutary. As we search deeper and deeper for the roots of each, we might find ourselves being pleasantly surprised by sources we denigrated as “woolly” or even (God help us!) “religious.” In particular, the study of cognitive development with respect to consciousness might open the way toward experiences that relate us to the cosmos as intimately as to the immediately available world.

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